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A STUDY OF SOME ALBERTA OILS IN RELATION TO SOURCE AND RESERVOIR BEDS AND VARIOUS PHYSICAL PROPERTIES

O. A. ERDMAN

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A STUDY OF SOME ALBERTA OILS IN RELATION TO SOURCE AND RESERVOIR BEDS AND VARIOUS PHYSICAL PROPERTIES

by

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A Thesis

submitted to the University of Alberta

in partial fulfilment of the require-

ments for the degree

of

MASTER OF SCIENCE

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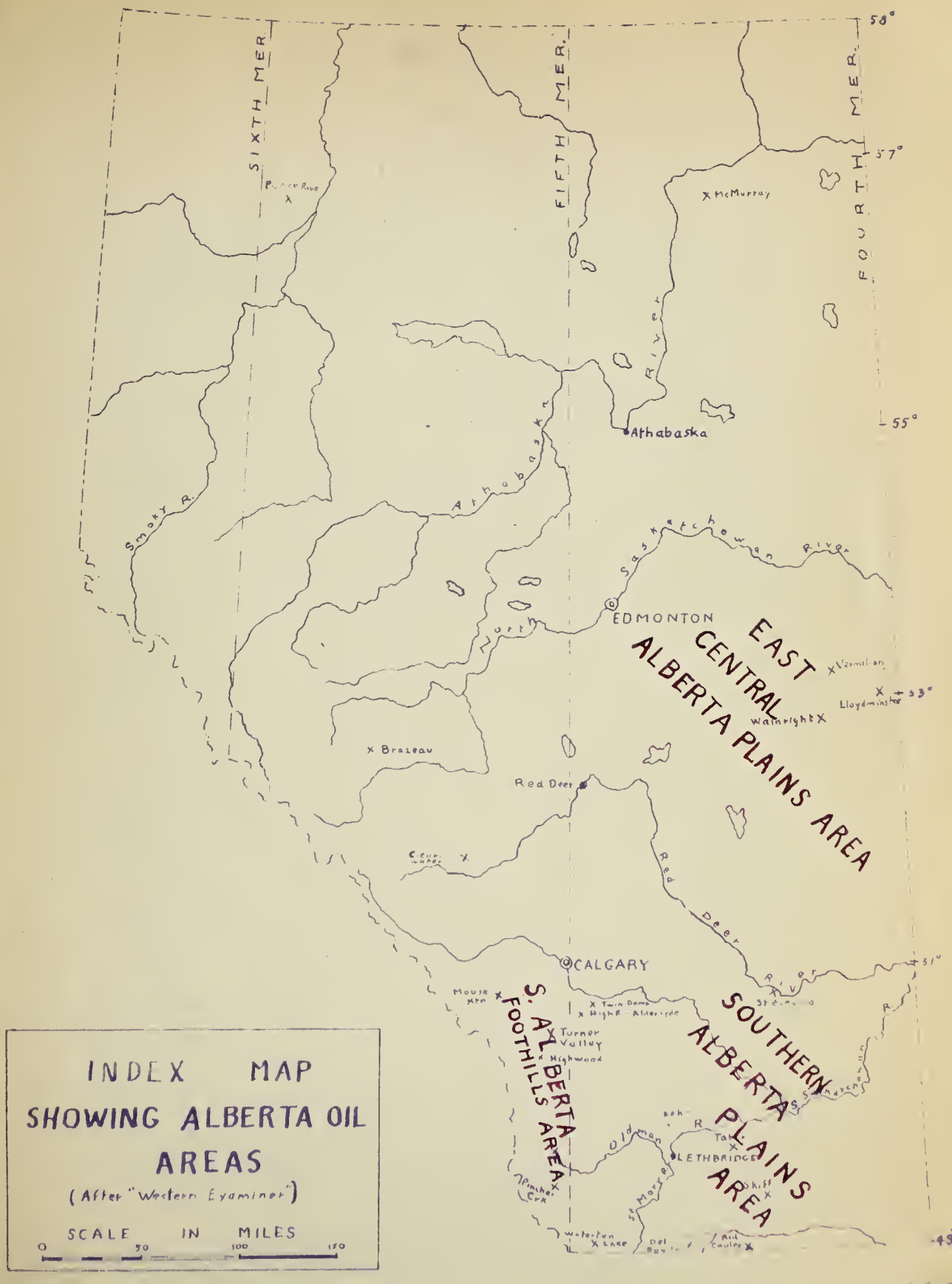

INDEX MAP
SHOWING ALBERTA OIL AREAS
(After "Western Examiner")

SCALE IN MILES
0 50 100 150

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CHAPTER I

INTRODUCTION

Introductory Remarks:

Investigations concerning the variations of the character of petroleum in relation to geology have been receiving increasing attention within the last few years. The problem offers an important and fruitful field for study. Probably the fundamental basis of this is that any change in the character of a crude oil might indicate a difference in source beds, reservoir beds or attendant geological conditions.

Barton (72,p.97) has suggested that the present character of crude oil could be expressed by the equation:

$$\text{Character of Crude Oil} = a(\text{source material}) \times b(\text{Age}) \times c\begin{pmatrix}\text{Depth factor:}\\ \text{Temperature}\\ \text{Pressure}\end{pmatrix} \times d\begin{pmatrix}\text{Chemical reactions:}\\ \text{sulphur}\\ \text{oxygen}\end{pmatrix} \times e\begin{pmatrix}\text{Dynamic Movement:}\\ \text{Temperature}\\ \text{Pressure}\end{pmatrix} \times f(\text{Regional Metamorphism}) \ldots\ldots\ldots N.$$

where a, b, c, etc. are the coefficients, and the parentheses enclose geological factors which should affect the character of the crude. Barton states further that a little investigated but important study

in petroleum geology concerns finding out what geological factors affect the character of crude oil and what is the effect of each factor.

This thesis represents an elementary investigation somewhat along the lines mentioned above.

Scope of Work:

Certain selected Alberta oils were investigated with respect to various properties and attempts were made to note relationships or similarities of the oil properties to geological factors. Oils investigated were mainly from the following areas:

Southern Alberta Foothills area,
Southern Alberta Plains area,
Central Alberta Plains area.

The division of areas is similar to that used by Beach(7) and Hume (26). The division is employed because it closely parallels the stratigraphical nomenclature. Since the discussion concerns geology and properties of petroleum further division into wildcat or unproved areas appears unwarranted. However, considering the limited and confidential nature of information from wildcat and unproved areas, the bulk of the data are derived from reports of commercial producers both past and present.

The relation of properties of petroleum to

source and reservoir beds as indicated in the title, introduces the geological aspect of the thesis, and creates one of the problems to be studied. Information concerning reservoir beds is largely concrete, but any hypothesis as to source beds should follow from a study of reservoir beds, properties of oil, stratigraphy, structure, and other factors.

The writer has limited the discussion of properties of oils to:

Gravity of oil,
Sulphur content (per cent by weight)
Carbon residue (per cent by weight)
Base of Oil
Color and Ultra-Violet Fluorescence

The source of most of the information on the first four mentioned properties was from literature and from correspondence. Some gravity measurements were made, and the fluorescence data was compiled from laboratory experiments.

The major part of the investigation in the thesis deals with fluorescence characteristics of Alberta oils under ultra-violet light. About 80 samples of oils were examined, also several related observations were made. Gravity of oil, sulphur content, carbon residue, base of oil, were dealt with

in relation to the geological studies of the areas.

The completeness of the investigations was limited by the available published information, and the number of oil samples at hand. The scarcity of published literature on properties of Alberta oil, and the small number of samples studied does not grant license for very much hypothesizing or theorizing. However, some results from such a study as this may be useful for possibly indicating the basis or direction of future work along these lines.

Previous Work:

The study of the character of petroleum in relation to the geology offers an important and fertile field for research (72). Present work of such a nature has been carried on by Bartram (6), dealing chiefly with the occurrence, and variation of the gravity of crude oils in the Rocky Mountain states. Barton (5) has analysed the variations of the character of the normal Gulf Coast crude oil as a function of depth and age, using such information as gasoline content, kerosine content, and base of oil. Reger (46) has quite recently carried out work on the crude oils of the Appalachian province, with respect to gravity of

oil, age of sands, and depths from the surface. Gravity variations with respect to metamorphic influences are very briefly mentioned. Taff (63) has studied the physical properties of Tertiary petroleums of California from the point of view of gravity variations, character of oil, origin and method of oil occurrence.

Concerning ultra-violet fluorescence of oil, no published work has been found for Alberta oil. In fact, very few references with respect to ultra-violet fluorescence of any oils could be located. Previous work has been done by Outerbridge (44) in the application of ultra-violet fluorescence as an oil test for industrial purposes. The work most closely related to ultra-violet investigations of crude oils is by Bentz and Strobel (9) concerning the application of ultra-violet fluorescence in oil geology. Recent study of ultra-violet fluorescence of crude oils has lead to applications in detecting small quantities of oil in drilling muds during operation (17). Radley and Grant (45) indicate a wide variety of uses for ultra-violet fluorescence in many major industries, as agriculture, manufacturing and chemistry. In the chemical world especially, ultra-violet fluorescence

investigations of organic compounds have been very marked during the last few years (75, 76).

The problem of the variations of the properties of oil with respect to reservoir beds, source beds, and structure has had ample opportunity for investigation in many United States and other developed oil fields. The method employed is in a large measure statistical, so that the greater the number of facts obtained the more specific the conclusions drawn. Considering the problem in Alberta, no field except Turner Valley has a sufficient number of wells to furnish necessary data. As far as the writer is aware no such studies have been made though certain trends, as the relation of gravity of oil to depth of limestone in Turner Valley, seem to be well known. Since Turner Valley is the only well developed field at present in Alberta and is very local in extent, the time has not come yet for any detailed investigation for Alberta concerning the variations of the properties of oil in relation to reservoir beds, source beds, and structure. This thesis represents an attempt to show, as far as present data permit, what variations are apparent in a few selected fields, between certain properties of oil and the geological factors mentioned above.

Acknowledgments :

The writer takes this opportunity to express his indebtedness to those who assisted in the compeletion of this work. Dr. J. A. Allan, under whose direction this thesis is prepared, gave valuable advice during the course of the work, and edited the dissertation. Dr. Allan kindly gave the writer access to information which would otherwise have been difficult or impossible to obtain, as well as access to the oil samples in the Department of Geology. Dr. R. L. Rutherford gave many helpful suggestions and pertinent information related with this work; he also checked the thesis. Dr. P. S. Warren kindly rendered advice in regard to certain questions on stratigraphy. J. A. Kelso kindly permitted the writer the use of Ultra-Violet apparatus and oil gravity hydrometers. The Department of Soils, University of Alberta, furnished several samples of soil.

The writer extends his sincere thanks to all those mentioned above and to various other persons who aided materially during the prosecution of this work.

CHAPTER II

GENERAL GEOLOGICAL DISCUSSION OF OIL AREAS

General Statement:

Before discussing the properties of some Alberta oils, it seems advisable to present a brief review of the geology of the areas concerned. Stratigraphy and structure will be emphasized because of the possible close relation of these aspects of geology to properties and occurrences of oil. More stress will be given to the older marine oil-containing rocks than to the younger strata of continental deposition.

Southern Foothills Area :

Location and Extent:

The general heading is employed because a few mentions are made to locations north and south from Turner Valley. However, for the purpose of this thesis the discussion related to the Southern Foothills areas has been largely limited to Turner Valley.

The folded and faulted region of the foothills area extends in a north-west direction and consists of nearly parallel ridges and valleys. The southern part of the area includes the disturbed belt of South-western Alberta, discussed by Stewart (60), while the whole of the area is embraced within the foothills belt

between the mountains and the plains to the east. The width of this belt is from 12 to 25 miles (26, p.66), and elevations range from 3,500 to 6,000 feet above sea level. In Turner Valley the elevations of the majority of producing wells are from 4,000 to 4,300 ft.

Stratigraphy:

Since most of the samples, and information on the properties of oil of the Southern Foothills area are from Turner Valley, the stratigraphical account will dealwith this field rather than generalizing for the whole area. References may be made to variations in the stratigraphy of adjacent parts. The table (Fig. I) shows the stratigraphy, lithology, thickness and the oil and gas horizons (29,31). The stratigraphical discussion is given in the order from the youngest to the oldest formations.

Tertiary: The youngest rocks in the Turner Valley field are the Paskapoo, non-marine sandstones and shales. These are present in the east edge of the foothills. The P askapoo is underlain by the Edmonton formation, but the division in the foothills is indistinct (54, p. 37).

Figure 1

TABLE OF STRATIGRAPHY FOR TURNER VALLEY

	AGE			FORMATION	THICKNESS (FEET)	DESCRIPTION AND REMARKS
	Tertiary			Paskapoo		Greyish ss., grey sh., conglomerate at base.
MESOZOIC	Upper Cretaceous	Montana	CRETACEOUS	Edmonton	1,110-1,500	Soft grey ss., greenish sh., in coal seams.
				Bearpaw	150-200	Grey shales, sandstones, coal seams. Shore phase.
				Belly River	1,600-1,700	Sandstones, dark & greenish shales. Coal seams. Non-marine.
		Colorado		Upper Alberta (Upper Benton)	1,700-1,800	Shale and sandy shale. Surface rock for most wells in naphtha-gas area
				Cardium	30-40	Grey sandstone and sandy shale. Pebble zones.
				Lower Alberta	800-900	Shale with thin sandstone bands. "Grit" at base. Marine.
	Lower Cretaceous			Blairmore	1,050-1,200	Sandstones and shales, coal seams in upper part. Productive oil and gas sands.
				Kootenay	0-100	Hard brown ss., and dark shales.
		Jurassic		Fernie	200	Brown thin bedded ss., dark sh., limy bands, phosphatic material. Small oil and gas.
PALAEOZOIC	Lower Carboniferous			Rundle		Mainly ls., cherty in places. Dolomitic zones. Main oil reservoir within upper 450 feet.

Upper Cretaceous: The non-marine Edmonton formation of sandstones and shale, bentonitic and ferruginous sandstones, and thin coal seams, overlies the marine Bearpaw. In Turner Valley the Edmonton formation is about 1,100 feet in thickness.

The Bearpaw formation is a marine to near-shore series of shale, sandstone bands, thin coal seams and bentonite. Hume (31) gives a thickness of 150 to 200 feet.

The Belly River formation underlies the Bearpaw and consists of 1,600 to 1,700 feet of non-marine strata, alternating sandstones and dark shales. Coal seams are present in the upper part and a persistent band of coal occurs 20 feet above the base. The Belly River is the surface rock encountered by many wells drilling on the west flank.

The Belly River formation in Turner Valley is underlain by 1,700 to 1,800 feet of shales and sandy shales of the Upper Alberta ("Upper Benton") formation. The Highwood sandstone occurs in the west in the upper part of the formation.

The Cardium sandstone lies below the Upper Alberta, and in Turner Valley it is composed

of from 30 - 40 feet of grey marine sandstone and sandy shale. A thin pebble zone occurs about 150 feet above the Cardium sandstone, and another thin pebble zone occurs about 100 feet below the Cardium (31, p.2). Beach (7) employs these pebble zones in oil well schedules for Turner Valley. West of Turner Valley Hume (31, p.2) indicates that the Cardium sandstone is 250-300 feet thick, and includes the strata between the two pebble zones, plus the pebble zones, which have changed to conglomerates. With relation to oil occurrences the Cardium sandstone assumes some importance as shows of oil have been obtained in many wells (29).

The Lower Alberta shales "Lower Benton", comprise 800 to 900 feet of marine shale and thin sandstone bands. At the base of the formation lies the "Grit" bed, and 300 feet above the base occurs a coarse sandstone member, the "Jumping Pound Sand".

Lower Cretaceous : The Blairmore formation which underlies the "Grit" of the Lower Alberta shales, is composed of sandstone and green shales, with coal in the upper part. The lower part has brown limy sandstones and dark shales. The Stockmens sand occurs about 100 feet below the top of the Blairmore, and

produced gas in the Stockmen No. 1 well (7, p. 26). The production of oil in the New McDougall-Segur No. 1 well gave the name to the productive sand occurring about 220 feet below the top of the formation. A persistent coal seam lies about 650 feet below the top of the Blairmore, below which is the Home sand. Oil and gas production from a depth of 4,560 feet in the Home No. 1 well gave the name to this sand (7, p. 11). In the Dalhousie No. 5 well oil and gas were produced from a conglomerate and sandstone horizon at the base of the Blairmore. This is the Dalhousie sandstone (31, p. 3). The thickness of the Blairmore in Turner Valley varies from about 1,050 to 1,200 feet.

The Kootenay formation in Turner Valley consists of brown hard sandstones and carbonaceous shales with coal. The formation is from 20 to 100 feet thick in Turner Valley. An arbitrary division between the Kootenay and underlying Fernie formation is made at the top of the "Brown" sand (30, p.7).

Jurassic : The Jurassic is represented in Turner Valley by the Fernie formation. Thin bedded sandstones occur at the top, capped by the "Brown" sand. In the lower part are the dark to black shales

containing thin limy bands. The formation is marine and is represented here by a thickness of 200 feet.

Palaeozoic : In Turner Valley the Fernie (Jurassic) unconformably overlies the Rundle limestone (Lower Carboniferous). The Rundle is nearly equivalent to the Madison of Montana (37, p. 1623). In Turner Valley the Rundle limestone is the reservoir bed for the main crude oil production. Porous zones occur at the top part of the limestone, again at 150 to 200 feet below the surface of the limestone, while the lower porous zone is found above a grey or black lime about 450 feet below the top (30, p.7). The persistent upper porous zone is dolomitic, and has a thickness of 75 to 100 feet, while the lower porous zone, which is also dolomitic, suffers a variation from 20 to 120 feet in thickness and also changes in porosity (62). The Rundle limestone is not drilled through in Turner Valley but has a thickness at Moose Mountain of 1,400 feet (31, p.3).

Turner Valley Structure:

The interpretation of Turner Valley structure is being continually modified or changed as new well records become available. Link and Moore in 1934

(36,p.1423)

indicated a highly faulted, closely folded anticlinal fold, bounded on the east by a major overthrust sole fault which underlies the entire or a greater part of the structure. The complexity of the structure was suggested when these authors claim that certain characteristics of the Alpine nappes, the Jura folds, and the Scottish highlands are embodied in this area.

With evidence supplemented by later data and a structural peg model, Hume (30, p. 8) shows a composite nature to the faults, as well as underthrusting in southern part of Turner Valley.

The presence of drag folds associated with overthrust faults has been indicated (31, p. 4). The main one, the east side major overthrust fault has been quite well defined by drill penetrations. It has been noted in sec. 9, tp. 18, range 2, W5, and trends north-northwestward to sec. 24, tp. 20, range 3, W5. Hume believes (30, p. 11) that the east side fault splits into two before reaching the surface, on sec. 25, tp. 20, range 3, in the present northern part of Turner Valley. Although surficially the fault shows no great stratigraphic displacement, a break of nearly 4,000 feet is shown in the MacLeod No. 4 well records

in Central Turner Valley.

At the surface the east and west flanks of the main anticline dip at angles as high as 65 degrees, and with a striking symmetry. However, on the west flank in sec. 15, tp. 19, range 3, the dip of the Palaeozoic may be less than 15 degrees west. (31, p.4).

An important feature of the Turner Valley structure now known from drilling is the relatively simple substructure and gentle dips of the limestone, in comparison to the steep dips and complex surface structures of the Mesozoic rocks. Another feature of the Palaeozoic limestone in Turner Valley is the tremendous gas and oil closure. The productive oil closure is somewhat more than 2,000 feet, while the combined gas and oil closure is about 4,900 feet (31, p. 20).

Southern Alberta Plains Area:

Location and Extent:

This area lies in nearly the extreme southern portion of Alberta. Topographically, stratigraphically, and structurally it represents the northern extension of the adjacent Northern Great Plains of Montana into Alberta.

The oil area concerned with in this portion of Alberta may be limited on the south by the international boundary; on the east and west respectively, by the 110 degrees and 113 degrees meridians of longitude, and on the north by the Red Deer River. This limitation of the area is selected to include certain oils fields of the Southern Alberta plains, and at the same time to

facilitate a discussion of their stratigraphical relations.

Stratigraphy:

A table (fig. 2), after Williams and Dyer (70), Hume (26), Russell and Landes (53), indicates the generalized stratigraphy of the southern plains, together with occurrence of oil. In the description of formations, more stress is laid on those associated with petroleum than to the younger rocks.

Tertiary: Except for some Tertiary rocks in the Cypress Hills region of the extreme southeastern Alberta, and Tertiary rocks in the western edge of the delineated area, the youngest outcropping beds are Upper Cretaceous.

Cretaceous: The formations underlying the southern plains of Alberta can be correlated for the most part with the Montana division of the Upper Cretaceous (66, p. 155). The St. Mary formation occurs on the west side of the Sweetgrass arch. It is represented by 1500-1600 feet of buff, massive sandstones, essentially non-marine, with coal and carbonaceous beds at the base. In the southern part of the same area 100 to 135 feet of the brackish-water Blood Reserve formation indicate the retreat of

Figure 2.

GENERALIZED TABLE OF STRATIGRAPHY FOR SOUTHERN ALBERTA PLAINS.

	AGE		FORMATION	THICKNESS (FEET)	DESCRIPTION AND REMARKS
MESOZOIC	Tertiary		St. Mary River	1,600	Grey, buff ss., sandy sh., fresh to brackish water.
	Upper Cretaceous	Montana	Blood Reserve (Fox Hills)	100-135	Massive grey cross-bedded sandstone.
			Bearpaw	500-700	Predominantly dark shale. Marine.
			Oldman (Pale beds)	550-750	Light colored ss. and sh., coal seams.
			Foremost	250-400	Arenaceous and shaly beds, coal seams.
			Pakowki	0-900	Essentially marine sh., chert pebbles at base.
			Upper Milk R.	0-300	Grey, argillaceous shale.
			Lower Milk R.	0-300	Massive sandstone, concretions.
		Colorado	Alberta	1,200-1,800	Dark grey marine sh., some sandy beds. Gas., oil shows.
	Lower Cretaceous		Blairmore-Kootenay	250-650	Green and reddish sh sandy sh. Gas and oil
	Jurassic		Ellis	150-250	Dark sh., calcareous shale. Oil occurrences.
PALAEOZOIC	Lower Carboniferous		Madison	1,000	Light grey ls., porous and cherty on top. Lower part dark. Oil, gas.
	Devonian			900	Dark ls., dolomitic in parts. Oil shows
	Pre-Devonian				Limestone and dolomite

of the Bearpaw sea. The formation consists largely of massive, grey, cross-bedded sandstones.

The Bearpaw is the youngest extensive marine formation in this area. It is composed predominantly of shales containing thin bentonitic bands. The thickness in the southern plains varies from 726 feet at Lethbridge to 575 feet at Eyremore (26, p.134). Russell (51,p.9) states that the formation is considerably thinner at Del Bonita than at Lethbridge.

The essentially fresh water beds of the Oldman formation (Pale Beds) underlie the marine Bearpaw in southern Alberta. Light colored sandstones and shales are predominant. Coal seams occur in the upper portion. The thickness of the formation varies from 875 feet at Milk River ridge (26, p. 130) to 550 feet at Eyremore.

The brackish and fresh-water Foremost underlies the Oldman formation. It is composed of arenaceous and shale beds, with a frequent occurrence of oyster shell beds and coal seams. The thickness in the southern plains varies from probably 270 feet (49,p.3) in the Milk River area to about 500 feet in the Taber district (53,p.58).

Marine Pakowki shales underlie the Foremost beds in this area. The thickness ranges from zero feet

in the southwest to 900 feet north of Medicine Hat (ibid., p. 44). A zone of chert pebbles occurs at the base of the formation. In the Eyremore area Hume (26, p.185) attributes 80 feet of dark grey shales containing chert pebbles at the base, to the Pakowki.

The Milk River formation consists of upper beds of drab grey argillaceous sandstone and sandy shales underlain by lower beds of medium-grained massive sandstones containing numerous concretions. An isopach map of the Upper Milk River beds (53, p. 32) indicates a change in thickness of from 300 feet in the southwest to zero feet north of Lake Pakowki. For the Lower Milk River the isopach map (ibid., p. 29) shows a bilobate form for the wedge of sediments, and a thinning of strata from about 300 feet at the international boundary to zero feet at Medicine Hat. The trend of the isopach lines are northwest-southeast with the marked bow to the south occurring between Ranges 13 and 17, to Townships 1 to 7. In the Brooks area Hume (26,p.170) assigns a thickness of 485 feet to the undifferentiated equivalents of Pakowki and Milk River beds.

The marine Alberta formation underlies the whole of the southern Alberta plains. In this area the formation consists of an upper 1,200 feet of dark

grey shale, bentonitic horizons, and fine-grained thin sandstone beds, underlain by 500 feet of dark shale and grey sandstone. The total thickness of the Alberta shale in this area varies from more than 1,800 feet in the west to about 1,200 feet in the east (53, p.21). There appears little variation in the thickness of the formation from the Sweetgrass arch area in Northern Montana , to Taber, Alberta. (59, p.44). In the Taber district the thickness penetrated by drilling is given as about 1,880 feet (52, p.5). At Eyremore, Hume (26, p. 185) attributes a thickness of 1,550 feet to the Alberta.

This marine formation is closely associated with gas and oil occurrence. In southern Alberta, horizons in this formation yield shows of oil at Keho (ibid., p. 136) and commercial gas production at the Bow Island and Foremost fields (59, p. 46). In Northern Montana the Whitlash field obtains commercial production of gas and oil from sands of this formation (15, p. 712).

Lower Cretaceous: For the Milk River area Evans (18, p. 12) indicates the contact of the top of the Lower Cretaceous and the base of the Alberta shale

to occur where green and red shales lie below grey and drab sandstone. While Evans bracketted the whole of the Lower Cretaceous in the Milk River area as "Kootenay", recent work in southern Alberta denotes this series as "Lower Cretaceous" (53, p. 16).

In a generalized table of the formations in Red Coulee for strata between Ellis (Jurassic) and Colorado, Yarwood (71, p. 38) shows 605 feet of red, green, variegated shales with sandstone lenses, and gas and oil sands at the base. Hume (26, p. 124) gives the thickness of the formation considered to be Lower Cretaceous at Red Coulee and Eyremore as, respectively, 540 feet and 410 feet. Thinning of the formation takes place also from west to east.

The general basal sandy zone of the Lower Cretaceous has produced commercial quantities of oil in Border-Red Coulee, Cutbank and Flat Coulee fields (49, p. 8). Some Taber, Alberta, wells are reported to have given oil or oil and water in the basal sandstone of the Lower Cretaceous (52, p.6).

Ellis (Jurassic): The Ellis (Jurassic) formation in southern Alberta is considered (26, p. 122) to be separated from the overlying Lower Cretaceous by a disconformity. From a study of oil logs in southern

Alberta, Russell and Landes (53, p. 14) generalize that there are from 150 to over 250 feet of Jurassic beneath the southern plains. The rocks consist of dark, somewhat calcareous shale, with limestone, and occasionally a basal sandstone. Irwin (34, p. 2) has indicated that the Ellis is in part equivalent to the Sundance (Upper Jurassic) formation of southern Montana and Wyoming, and in part to the Fernie of the foothills in Alberta. On foraminiferal evidence, Wickenden (69) has shown a similarity of fauna from certain southern Alberta and southwestern Saskatchewan wells to fauna of the Sundance formation in southeastern Montana.

The lithology and thickness of the Ellis vary considerably throughout southern Alberta. In the Red Coulee field the Jurassic is represented by an average thickness of 60 feet of greenish grey calcareous shales (71,p.41). Collier (13, p.67) indicates an average thickness of 238 feet for the Ellis on the north side of the Kevin-Sunburst dome of northern Montana. A location at East Butte in Montana, has exposed the entire Jurassic. Sanderson (55,p.30) measured 306 feet of dark marine shales and limestones, with sandy phases toward the base. At the Eyremore well the Ellis has lost its typical character, and is doubtfully

represented by 60 feet of grey calcareous shales and siliceous sandstones (26, p. 121).

The Ellis is one of the most important formations in the southern plains in regard to petroleum, as it is considered as both a source and reservoir bed (55, p. 29). Oil occurs in this formation at Cutbank, Kevin, Sweetgrass Hills in Montana, and Skiff, Alberta. Oil shows at the Jurassic-Palaeozoic contact are very frequent throughout the southern Alberta plains.

Palaeozoic: The bevelled Palaeozoic (Mississippian) limestone in the southern Alberta plains, underlying the Jurassic formation, represents a major unconformity. The Mississippian rocks in the southern part of the area are correlated with the Madison formation in Montana (53, p. 12). Moore (40, p.17) has described the marine Madison formation in southern Alberta as composed almost entirely of a very uniform limestone. The lower part of the Madison is quite thin-bedded, of a shaly character, and may contain fine-grained, grey, limy sandstone. Deep weathering effects have been noted in all wells penetrating the limestone in this area. Cherty phases occur also in the upper portions of the lime. The thickness of the Mississippian is quite irregular, showing a decrease

from the south to the north from 1,100 feet near the international boundary to about 750 feet at Eyremore (26,p.121).

Oil and gas occurs near the top of the Mississippian at Del Bonita (8, pp. 79, 109). Shows of oil are indicated at similar horizons in other wells of the southern plains.

Devonian: In the Sweetgrass arch area Collier (13, p. 62) indicates a probable unconformity between the Mississippian and Devonian strata. About 20 miles north of the international bounday, in the Commonwealth-Milk River well, Spratt (26, p. 154) has attributed 895 feet of grey, dark, limestones and some anhydrite, to the Devonian. Moore (40, p.21) has indicated the upper contact of the Devonian at the black, fissile, in places, bituminous shale. In the Eyremore area strata similar to the Devonian of the Commonwealth-Milk River well are recorded (53, p. 10). Correlations have been made for the Devonian in southern Alberta with Three Forks (late Devonian) and the Jefferson (Middle Devonian) of Montana.

The Ordovician and Silurian formations are apparently missing under the southern Alberta plains, as the Pre-Devonian rocks encountered in the Common-

wealth-Milk River well are believed to be Cambrian (40, p.25). The series consists of grey to brown limestones and dolomites, with some thin bands of bituminous shale and limestone.

The total thickness of the Palaeozoic under the southern Alberta plains is not definitely known. In the Steveville area, according to preliminary information the Princess No. 1 well entered the Palaeozoic at 3,195 feet, and reached the base of the Palaeozoic at about 6,145 feet. This represents a total thickness of about 2,950 feet for the Palaeozoic in this area.

Structure:

The most prominent structural feature in the plains of southern Alberta is the northward-plunging Sweetgrass arch (40, p. 26). This arch is a great uplift from the neighborhood of Great Falls, Montana, northward to beyond the Canadian boundary (13, p.77). Michener (39, p. 52) has indicated a swing in the direction of the arch axis in southern Alberta from west to north to northeast. North of Medicine Hat the arch is considered to lose its identity. The western flank of the Sweetgrass arch passes into the Alberta syncline with an increased dip and a marked thickening of formations (ibid., p. 52). The laccolithic domes

that form the Sweetgrass Hills interrupt the formations on the east side of the arch, but are not themselves properly a part of the arch (ibid., p. 53).

The importance of the major Sweetgrass arch is due to the fact that local irregularities on the main arch represent the reservoir beds for many of the southern Alberta oils. It may seem peculair that an anomaly exists with respect to the low oil production in southern Alberta as compared with the production of the adjacent northern Montana oil fields. The fact appears (50, p. 194) that the Sweetgrass arch has affected the potential structures of oil, by producing sufficient gradient northward so that few southern closures exist in Alberta, and the oil has migrated up dip toward Montana.

In southern Alberta the most prevalent type of local folding on the Sweetgrass arch are northwest plunging noses. A summary of structures for some oil fields in this area will indicate examples of these plunging noses directly associated with the arch as well as structures apparently not related.

Red Coulee: The Red Coulee structure represents a local northward plunging nose on the Sweetgrass arch. Evans (18, pp. 23, 24) describes it as a narrow, plunging

arch close to the foot of a fairly steep terrace slope. In regard to this structure most of the producing wells lie just south of the international boundary, so that the location of the Red Coulee wells seem to represent the northern extremity of the plunging nose. The commercial oil production is from the Vanalta sand, 50 feet above the base of the Lower Cretaceous.

Del Bonita: Russell (51, p. 10) has demonstrated the structure of Del Bonita as being an anticline and syncline plunging to the northwest. Structural contours on this anticline as drawn at the top of the Belly River (ibid., map) indicate a high of 3,900 feet above sea level at the international boundary and a minimum of 3,400 feet above sea level in the adjacent syncline to the east. In the Del Bonita wells the main gas and oil occurrence is near the top of the Palaeozoic limestone (7, p. 109)

Taber: The structure in the Taber district has been worked from rock outcrops, coal mine and oil well records. Russell and Sproule (52, p. 6) indicate evidence for a structural dome or nose southwest of Taber and centering around sec. 13, and sec. 24, tp. 1, range 17. Several small northward plunging folds as represented by contours on top of the Taber coal seam

(Foremost) appear related to the main dome (53, map). It is not know whether the Taber structure is closed completely, but a closure of 30 feet on the southwestern side, and a closure of over 50 feet on the southeast flank seem evident. Strong shows of oil or oil and water have been obtained in the basal sandstone of the Lower Cretaceous.

East Central Alberta Plains Area:

Location and Extent:

The somewhat arbritarily chosen northern limit for the Southern Alberta Plains, viz., the Red Deer River, may be taken as the southern boundary of the East Central Alberta Plains area, while the northern extent may be defined by the North Saskatchewan river. The eastern extent is determined by the Alberta-Saskatchewan boundary line, and the western edge may be roughly denoted by longitude 113 degrees west. The stratigraphical nomenclature is fairly uniform within this delineated area.

Stratigraphy:

The area concerned with in this thesis centres around Wainwright, Lloydminster, Vermilion; therefore the stratigraphical considerations will be applicable to this smaller unit. The stratigraphy, lithology,

thicknesses, and horizons of gas and oil occurrences are shown in figure 3 (1, 26, 32, 68). A brief review of the formations is given in descending order:

Bearpaw formation: The Bearpaw shale is the youngest rock exposed in the western portion of the area as outlined. It is not considered to extend far north of the North Saskatchewan River (2,p.22) but is quite prominent in the southern part of the area under discussion. On the Red Deer river a thickness of 600 feet has been assigned to a series of marine shales and shaly sandstones (1, p.12).

Belly River Series: This term as employed here includes in descending order, Pale beds, Variegated beds, Birch Lake formation, Grizzly Bear formation and Ribstone Creek formation. There is no sharp contact between the Pale and Variegated beds. These are not separated on the latest geological maps. A gradation in lithology is indicated (24, p. 7) between the upper beds which are pale colored, cross-bedded sandstones containing thin coal seams, and the Variegated beds, which consists of interlayered sandstone and shales of various tints, plus thin coal seams. The Pale beds are continental with a thickness of about 500 feet. The Variegated beds show both fresh and brackish water

Figure 3.

GENERALIZED TABLE OF STRATIGRAPHY FOR EAST CENTRAL PLAINS

	AGE		FORMATION	THICKNESS (FEET)	DESCRIPTION AND REMARKS
MESOZOIC	Upper Cretaceous	Belly River Series	Bearpaw	600	Marine sh., shaly ss.
			Pale beds	500	Light grey ss., coal seams.
			Variegated beds	200	Interlayered ss. and sh. Thin coal seams.
			Birch Lake	60-100	Massive, buff, cross-bedded ss., hard lenses. Brackish and marine.
			Grizzly Bear	40-100	Dark grey marine shales, ss. and ironstone nodules.
			Ribstone Creek	325	Massive, soft ss. at top carbonaceous sh., coal and grey ss. at base. More marine in East part.
			Lea Park and Alberta	1,450-1,700	Grey marine sh., some sandy beds. Chert pebbles at base of Alberta. Gas showings in Lea Park. Gas and oil showings in Alberta shales.
	Lower Cretaceous			150-550	Dark shales, grey to white ss. Coal seams. In Lloydminster area formation contains more sand. Main oil production.
PALAEOZOIC	Mississippian (?) and Devonian				Grey dolomite and ls., shaly in upper part. In Lloydminster area sandy zone near top. Oil shows.

characteristics. The thicknesses at Wainwright and on the North Saskatchewan River are about 200 feet (58, I).

The Birch Lake sandstone underlies the Variegated beds, and consists of from 60 to 100 feet of massive, buff-colored, cross-bedded sandstone, with lenses of harder sandstone present. The beds are mainly from brackish water deposition, but near the base contain a marine fauna (65, p. 10).

The Grizzly Bear formation varies from 40 to 100 feet in thickness, and consists essentially of dark blue to grey marine shales containing ironstone and sandstone nodules (24, p. 3). In the Lloydminster area no exposures of this rock are known to occur, but the shale which is encountered in some oil wells below the glacial drift and above sandy beds may belong to the Grizzly Bear (16, p. 264).

The Ribstone Creek formation in the Wainwright-Vermilion area consists of greenish-yellow, massive, soft sandstones at the top, with carbonaceous shales and coal; and grey sandstone at the base (24, p. 3). In this area the formation consists of 325 feet of fresh to brackish water deposits. In the Lloydminster area

the formation consists of 325 feet of fresh to brackish water deposits. In the Lloydminster area the Ribstone Creek formation is encountered in oil wells within about 220 feet from the surface. It is represented by alternating marine and none-marine beds, while to the east the formation is composed wholly of marine beds (32, p. 2). Small gas showings have been encountered in this formation.

Lea Park and Alberta Shales: The Lea Park marine shales constitute the oldest known rocks exposed in the East Central Alberta Plains area, while the underlying Alberta shales are the oldest Upper Cretaceous rocks present. In the type locality the upper 375 feet of the Lea Park is exposed, and is composed of brownish and yellowish shales on top, with dark grey marine shales below, (1, p. 13). The base of the Lea Park has not been observed in Alberta so that the thickness assigned to the formation depends where the contact with the underlying Alberta shale is placed. An estimated 700 feet has been given as the total thickness for this formation (58,68). In the Wainwright-Lloydminster-Vermilion area the top of the Alberta shale has been placed just above a speckled shale (26, p.190). This division would give a thickness to the Lea Park of

from 900 to 1,000 feet in the Wainwright-Vermilion area, and about 800 feet in the Lloydminster area. On this same basis the Alberta shale would have a thickness of about 500-700 feet in the Wainwright-Vermilion area, and about 700 feet in the Lloydminster field. The Alberta shale is comprised of grey marine shale with some sandstone beds, and nodules. In oil wells the base of the Alberta is marked by a persistent horizon of smooth, black chert pebbles (27, p.6). Gas showings are encountered in the Lea Park, while some oil and gas is found in the shales of the Alberta formation.

Lower Cretaceous: In the Wainwright-Lloydminster-Vermilion area, the Lower Cretaceous appears to be separated from the Alberta shales by a lithological breack, as indicated by the chert horizon. A major time break between the Lower Cretaceous and the Palaeozoic limestone exists in this area. The Upper Jurassic beds which occur above the limestone in the Southern Alberta plains do not carry this far north. Grey and dark shales alternating with light grey to whitish sandstones constitute the prevalent rocks of the Lower Cretaceous, but in the Lloydminster wells (16, p. 265) sands and sandstones are very abundant. A coal seam which appears to indicate a very definite horizon, occurs 130 feet below the top of the Lower

Cretaceous in the Wainwright area, and 150 feet below the top in the Vermilion area (32, p. 6). Since the formation indicates deltaic conditions and was originally deposited on an erosional surface, it is not surprising to find wide differences in thicknesses. The thickness of the Lower Cretaceous is from 250 to 300 feet in the Wainwright area, and as high as 470 feet in a well on the Battleview anticline 20 miles north-northeast of Wainwright. In the Ribstone and Lloydminster areas the Lower Cretaceous is up to 560 feet in thickness. In the Vermilion area about 300 feet represents the thickness of the Lower Cretaceous. Oil and gas occur in the Lower Cretaceous, but the main oil production is from the top of the Lower Cretaceous and from sands below the persistent coal seam.

Palaeozoic: The Palaeozoic limestone has been reached in several wells in this area at depths from 2,000 to 2,500 feet below the surface. In the Wainwright area the lithology varies from white to grey dolomite and limestone with some calcareous shale in the upper part, to buff dolomites containing red and green shales (27, p.4) In the Lloydminster area limestones have been encountered in one well, where 50

feet of limestone overlies at least 30 feet of sand" (16, p. 265). Twenty miles south of Lloydminster over 800 feet of limestone overlies a sandstone bed of similar stratigraphic position to that at Lloydminster.

The age of the Palaeozoic in this area has not been definitely shown. At the Duvernay well, about 75 miles northwest from Wainwright, strata occurring below 90 feet in the limestone, lithologically resemble the Devonian at McMurray, and fossil evidence indicates a relation with the Simpson shale (Upper Devonian) on the MacKenzie River (67, p. 149). Small oil shows have been encountered in the Palaeozoic rocks of the Wainwright area.

Structure:

The regional structure of the Wainwright-Vermilion area is assumed to be a terrace with a very slight dip to the southwest (24, p. 8). Further east in the vicinity of Battle River the dip changes to southeast. Flexures such as the Hawkins, Fabyan, Battle River-Wainwright, Ribstone, and Battleview folds occur as minor folds on the major structure, and afford structures for gas and oil accumulation. The majority of these folds seem to extend in a northwesterly-southeasterly direction. The Battleview fold occurs

about 15 miles north-northeast of Wainwright or east of the Hawkins, Fabyan, Battle River-Wainwright folds and west of the Ribstone-Blackfoot fold. The known closure as determined from surface information exceeds the known closures of any of the folds to the west of it, and is apparently sharper than the closure of the Ribstone-Blackfoot anticline (27, p. 14). Very little detailed information is available on these minor structures.

The Lloydminster area is believed to be situated near the "high" of a broad anticlinal structure. The crest of the Ribstone-Blackfoot anticline south of Lloydminster, has been considered to extend northward into the Lloydminster area. A minor structure developed on this broad arch apparently forms a local structural high in tp. 49, and three-quarters of a mile east of the Alberta-Saskatchewan boundary line (16, p. 266). No information has been available concerning the local structure in the Vermilion area.

CHAPTER III

GENERAL PROPERTIES OF OIL

General Statement :

This chapter concerning various properties of oil serves as a background for the discussion of Alberta oils. The properties of oil considered here will be very largely limited to those specifically dealt with in the following chapter, viz., gravity, sulphur content, carbon residue, base of oil, and ultra-violet fluorescence of oil.

Clarke (12, p. 731) has stated that natural gas, petroleum, bitumen, and asphaltum are all essentially mixtures of carbon and hydrogen compounds in a great variety, although the principal hydrocarbons present are paraffins and naphthenes (48, p.8). Many impurities occur in the free or combined state, such as sulphur, oxygen, nitrogen; small amounts of rarer ingredients such as nickel, vanadium, and phosphorus may be included (35, p.16). Considering such a variety of impurities and the great number of possible combinations of hydrogen and carbon that could affect the characteristics of oil, it may be somewhat startling that any agreement exists among

corresponding properties of different oils. Oils of similar properties may occur widely separated geographically. This aspect is not dealt with here, but rather, the possible relation of properties of oil to geology will be emphasized. The variations of some properties of petroleum with certain geological conditions as investigated in a few fields outside of Canada, will be briefly reviewed, as it may serve as a criterion for comparison of results of work as found for Alberta oils.

Gravity:

The gravity of crude petroleum appears to differ depending on many conditions. Recently work has been done in the United States to determine variations of gravity with sulphur percent, with base of oil, with depth to oil sands, and with age of reservoir beds.

For normal Tertiary Gulf Coast crude oil Barton (5) has obtained the following results. A simple solution of one percent sulphur in the crude produces a decrease of 1.8° A.P.I. In regard to the abnormal content of sulphur there is an inverse ratio, and the rate of decrease for the gravity is indicated as between 35° A. P. I. and 15° A. P. I. per one per-

cent of sulphur. The general law for the variation of gravity with depth in this case was, that for crude oil of the same age the A.P.I. gravity and the content of the light constituents tended to increase with depth of producing sands. Irregularities and reversals of this general rule were evident in certain cases. With regard to the variation of gravity with age of the reservoir rock the A.P.I. gravity and the content of lighter constituents tended to increase for crudes from the same depth.

Variations of gravities for California oils, are cited by Taff (63, p. 229). In regard to several oil fields on closed but imperfectly sealed anticlinal structures, the gravity becomes heavier in the upper strata, ranging from 27°-40° A.P.I. in the lower strata to 23°-35° A. P.I. at the top. With respect to completely sealed, closed domes, containing gas under pressure, as the Kettleman Hills and Ventura fields, different results were indicated. In the Kettleman Hills field the light naphthene oil showed a grading upward from 34.2° A.P.I. at the bottom to 68.3° A.P.I. at the top; the oil of the Ventura field gave an uneven variation from 30° A. P.I. in the lower part to 56°

A.P.I. in the upper strata.

The gravities of oil in the Rocky Mountain region have been discussed by Bartram (6). The main investigation concerned variation of gravity with reservoir beds. No general trend for gravity to age of formation is indicated. Rather anomalous cases are cited where heavy oils are produced from sharply folded structures, while lighter oils are obtained from gentle domes of the same age.

Sulphur Content:

Sulphur occurs in petroleum nearly universally in small amounts, but cases are frequent where the content is very high. Sulphur is seldom present in the elemental form but most commonly combined chemically with carbon and hydrogen (12, p.736). Lilley (35,p.31) indicates the dominance of sulphur compounds in heavy oils. Hamor and Padgett (23,p.325) show graphically for a California field that the gravity of oil becomes heavier as sulphur content increases. A normal decrease of the sulphur content for the Tertiary Gulf Coast crude oils has been shown to occur from the shallowest Miocene to the deeper Eocene sands.

Carbon Residue:

The term does not refer to the carbon in the chemical sense but to the percent of solid carbonaceous substance remaining after the volatile material has been driven off from the residuum of the distillate. Nelson (41,p.48) has stated that only scant data were available concerning the materials producing carbonaceous deposits; asphaltenes, carbenes, and floridin tars were classed in this group, but references were given to show that pure paraffin and naphthene hydrocarbons did not form carbon in the carbon residue test. Thom (64,p.79) indicates that non-volatile carbonaceous residues from which the more volatile fractions have been driven off, are found in the form of such substances as grahamite or asphaltite filling fissures in highly altered younger sediments; as disseminated carbonaceous material in older, more lithified black shales; and as anthraxolite or graphite in highly altered pre-Cambrian sediments.

The carbon residue content of some typical oils shows 1.3 percent for a West Virginia oil, to 7.2 percent for a Peru oil, to 22.8 percent for a Mexico oil (35,p.33). Some variations of the "carbon" content

with respect to reservoir beds have been noted by Barton for the Tertiary Gulf Coast crude oils (5). The general rule in this case appears to be a decrease of "carbon" content with increasing stratigraphical age, where producing beds are the same depth; and a decrease of "carbon" content with depth, where the beds are of similar age.

Base of Oil:

Criteria for determination of base of oils:

The United States Bureau of Mines and the Department of Mines in Canada employ nearly identical methods for the determination of base of oils. Since reference will be made to the base of Alberta oils, the method as used in Canada by Rosewarne, Chantler, and Swinnerton (48) will be described.

If the gravity of the 250°-275° C. fraction at atmorpheric pressure, is lighter than 40° A.P.I., the crude is considered of paraffin base. If the gravity of this cut is between 33° A.P.I. and 40° A.P.I., the base is classed as intermediate; and if the gravity is heavier than 33° A.P.I., the oil is either of a naphthene - or hybrid - base. As a supplementary distinguishing criterion the cloud point variation is

employed. If the cloud-point of the 275°-300° C. cut, at 40 mm. pressure, is below 5°F., the oil is classed as having a naphthene base. Presence of wax is indicated by a cloud-point above 5°F., in which case the base is either paraffin, intermediate, or hybrid, depending on the gravity of the 250°-275° C. cut as indicated above. This empirical set-up classifies the majority of the world's petroleums into four groups as defined.

Variation in base of oils:

From a statistical survey of some United States oils, Barton (4,p.145) observes that the trend of the character of base is as follows:

Young oil	-	naphthenic
Middle-age oil	-	intermediate toward naphthenic
Old-age oil	-	intermediate toward paraffinic

According to this the evolution of crude oil is from the naphthenic series toward the paraffinic series. Basing his conclusions on laboratory results, Berl (10) believes that asphalts are the parent material of crude oil and through their transformation aliphatic, aromatic, and hydroaromatic hydrocarbons can be formed. On the other hand, age-character relationships for oil, wholly the reverse from the above, are held by Seyer(56).

There is evidently much need for investigation to be done in this respect to determine if or what other factors enter in modifying or affecting the base of crude petroleum.

Fluorescence of Oils in Ultra-Violet Light.

Principles of Fluorescence.

Norrish (43) has defined fluorescence as the reverse of light absorption. It consists of the re-emission of light energy, without any permanent change in the structure of the absorbing system. Fonda (19) notes that fluorescence is frequently associated with the presence of a foreign ingredient at low concentrations. He compares such fluorescence with the resonance radiation of gases under low pressure, where the exciting illumination has a wave length corresponding to an absorption band of the gas. Resonance is induced in the atoms, or molecules of the gas through the absorption of energy to so great an extent that an electron is driven to an outer orbit. Luminescence results when the electron returns to its normal orbit. In this case the wave length of the exciting radiation equals the wave length of the luminescence radiation.

The case of liquids and solids appears more complicated. While the exciting indication may be monochromatic the fluorescence may extend over a broad band of the spectrum. Although very often the emitted ray has a larger wave length than the activating ray (Stokes' Law) Nichols and Merritt (42, p. 13) have shown by studying fluorescence of fluorescein, eosin, napthalin-roth, that the law is not universally applicable.

Fluorescence is exhibited by a large number of organic products, such as eggs, plants, milk products, petroleum, print and paper (19, p. 1). Although may inorganic substances do fluoresce, Lehmann (45, p. 114) has shown that in the pure state they usually show little or no fluorescence in ultra-violet light.

Application of Ultra-Violet Fluorescence in Petroleum Geology:

The application of ultra-violet light in petroleum geology has its basis in the fact that certain crude oils when exposed to such a light emit visible colors. Bentz and Strobel (9) mention the practical uses of ultra-violet light in Germany, in respect to petroleum.

First, distilled and refined oils can be easily distinguished by lack of, or difference in, luminescence of the latter mentioned oil.

Second, crude oil can be easily identified from accidental contamination, thus possibly saving further investigations. In this connection Bentz and Strobel (ibid.) cite a case which may have been provoking, but for the rapid examination under ultra-violet light.

Third, the method can give an approximate clue to the character of an oil-show, whether it be light or a heavy asphalt-rich oil. This application can be of importance in exploratory work where shows are too small to admit of chemical analysis.

Fourth, Bentz and Strobel (ibid.) state that in oilsand cores, the smallest shows of oil can be proved by their intense luminescence against the dark violet color of the rock. In this connection in North America the "Baroid Well Logging Service" (3) utilize an ultra-violet light to observe the first indications of oil in the drilling mud. This simply consists in passing the drilling mud past an illuminated ultra-violet zone and observing, by visual magnification apparatus, any slight trace of oil.

Several related applications of ultra-violet are worthy of mention. With respect to drill cores the fluorescent light may show if the oil impregnations are irregularly spotted, whether they lie in a stratified manner, or whether they are related to chasms in the rock. This application was found very useful especially when the oil containing rock was of a dark color (9). For instance, concerning the "Hauptdolmit" of the Middle Zechstein (Permian) of Thuringia, the bitumen content could not be determined at first sight because of the rock color. However, when this was illuminated under the ultra-violet light, shows of bitumen were obtained, greatly enriched in clefts and chasms in the rock. The impression that Bentz and Strobel (ibid. p. 336) gathered from this observation was that the "Hauptdolmit" is a primary oil-carrying rock whose bitumen has suffered only slight migration.

These cases show the possibilities that a systematic investigation of core samples may have in giving clues or supplementing observations as to the kind and origin of crude oils.

Method of Observation in Ultra-Violet Light.

Preparation of Samples:

Observations of crude oil samples by Bentz

and Strobel (ibid., p. 334) were made on both blotter paper and watch glass. The measurements of the luminescent color and intensity were visual. Radley and Grant (45, p.113) mention a reference where examination of lubricating oils and greases is recommended to be made in a thin film on a glass slide, or impregnated into filter paper.

Methods developed by Engineering Laboratories, Inc., Tulsa, Oklahoma (17), for the detection of extremely small amounts of petroleum in the drilling mud, utilize a mercury-vapor lamp, a special glass filter, and a large magnifying glass for visual observation.

The capillary luminescence analysis mentioned by Germann (20) is considered because of some relation of the writer's preparation of samples to those employed under this method. The capillary method of analysis makes use of an absorbing medium as filter paper. Liquids are applied and allowed to expand by capillary action to a definite limit. Examination follows standard procedures and is done objectively by photometer and galvanometer.

For this study the writer tried out several methods of preparation of the samples to be examined. Crude oil was applied to blotter paper and filter

paper. A drop of the oil on a glass rod was touched against the absorbing medium and allowed to spread by capillary action. Samples of the crude oil for ultra-violet observation were poured into small watch glasses, and the ultra-violet light permitted to act directly on the oil. In this case the walls of the ultra-violet light case acted as a black background. Glass mounts of the sample oil were also attempted. This involved application of a small amount of oil to the surface of the glass slide, placing on the cover glass, and sealing off the edges with mucilage.

The filter paper method was adopted in preference to the other, for carrying out tests. The visual results harmonized quite closely with those of the other methods mentioned. Any change of the luminescence colors, caused by exposure to air did not appear to be great enough to warrant the use of the glass mount procedure outlined above. Samples on watch glasses did not provide a ready means for comparative description of samples. Also in the case of lighter oils, the evaporation of the oil on the watch glass in some cases effected a change of luminescent color as time went on. This change was believed to be due to the concentration of color in the heavier

fractions remaining as the more volatile fractions vaporized.

The filter paper method largely obviated these difficulties. Evaporation of the lighter oil during a period of several days did not appear to have very much affect on the color and intensity of the oil stain luminescence on filter paper. This was demonstrated by a simultaneous comparison of fresh oil stains with those prepared over a time period. For reason of this factor, and the fact that up to 20 oil stains could be applied to one filter paper and thus examined comparatively, the filter paper method was employed for the retention and observation of the oil samples.

The actual preparation of Alberta oil for observation consisted in application of a drop or less of the sample oil to 699 C English Filtering paper (diam. 18.3 cm.), and allowing capillary spreading. The filter paper was thus impregnated with several separated circular stains of crude oil. One sheet of paper may contain as many as 15 stains of 15-20 mm. diameter. After the first extensive spreading of the oil drop had ceased, it was examined under ultra-violet light.

Examination of Samples.

The great difficulty in ultra-violet examination is the precise measurement of colors and intensities. Reference is made by Germann (20) to Beutel and Kutzelnigg who in 1931 used a photometer to make a more exact study of fluorescence in minerals. The later methods as the color and luminescence compensator of Rojahn and Heinrici, as well as Haitinger's modified prism are also mentioned.

Germann and Hensley (21) eliminated personal error by their employment of an objective method for evaluating fluorescence. The method was adopted for a precise study of fluorescence of porous paper on which a fluorescent liquid had been permitted to spread through capillary action. The special requirements were met by a photo-electric cell, and total energy rather than color, was measured. A sodium nitrite filter cell was employed to absorb the ultra-violet and transmit the visible. The recording unit was a sensitive galvanometer. Following earlier investigators, these authors chose a fluorescent material as a standard, in this case a plate of uranium glass. This method has been mentioned because it is one of

of the most recent investigations of qualitative ultra-violet examination of fluorescent liquids.

The observations of the Alberta crude oil samples were carried out in a dark room. Earlier examinations were made under a large cabinet model Mercury-Vapor light, where the ultra-violet rays were permitted to pass through the glass front. All later examinations were done under a portable ultra-violet lamp, series 370 of "Ultra-Violet" Products Inc. This lamp was equipped with a special ultra-violet black light filter which allowed a passage of rays of 2537°A.

The actual measurements of color and intensity of the luminescence for the samples were entirely visual and comparative. An oil-spotted filter paper was subjected to the ultra-violet light. The specimen stains were compared relatively for color and intensity of luminescence. Since the cabinet was sufficiently large to hold simultaneously two sheets of the filter papers, there was always a control sheet under observation. Roughly descriptive color phrases were used in referring to the samples, but very delicate distinctions could not be described exactly, and were

therefore comparatively discussed.

An attempt was made to match visually the luminescent colors for the crude oils, with colors in the Ridgway color catalogue (47). Difficulties were encountered due to the fact that the color chart was viewed under northern daylight, while the oil stains, under ultra-violet. Thus it was found impossible to match colors by actual coincidence of the color chart with the oil stain, and the results were not sufficiently precise. In fact small differences in tint could not be ascribed to a definite color plate in the catalogue, but were readily noted by comparison with other colors on the filter paper. The other difficulty was caused by necessity of maintaining a dark environment for the fluorescent lamp, simultaneously with daylight environment for the Ridgeway chart. For these reasons this absolute comparative scheme was abandoned in favor of the relative comparative method of describing luminescence colors among themselves.

The result of this method was that the majority of oils gave luminescent colors which could roughly be classified into a few larger color groups. Slight differences were noted by descriptive phrases.

A few oils showed so distinct a fluorescence color from the others that they were separately described.

It is impossible to portray to the reader the actual semblance of the luminescence phenomena. Some indications may be had, for supplementing the verbal descriptions, by the photographic comparisons of the filter paper sheets. These were prepared under similar light and exposure conditions, and are to show the relative differences in daylight as compared to ultra-violet light as translated by the photographic film.

CHAPTER IV

PROPERTIES OF SOME ALBERTA OILS.

Oils of the Southern Foothills Area:

Turner Valley Oil:

Reservoir Beds:

Mesozoic Oils: In Turner Valley shows of oil are common in the Lower Alberta shales, but the main production of Mesozoic oil has been from the Blairmore formation. The reservoir zones for gas and oil are discussed in descending order: The Stockmens sand occurs about 100 feet below the top of the Blairmore. It is a coarse to medium-grained sandstone and has a speckled appearance in well samples. Some gas has been produced from this zone. The McDougall-Segur sand lies about 200 feet below the top of the Blairmore. It consists of up to 200 feet thickness of sandstone, with some interspersed shale. Some oil production has been obtained from this sand in the northern part of the valley. The Home sand lies about 900 feet below the top of the Blairmore and consists of a white or grey granular quartz sand. Grey and greenish shales with calcareous sandstones occur below the Home Sand. The Dalhousie sand occurs at the base of the Blairmore and is composed of light calcareous sandstones containing abundant feldspar (22, p.230). Small quantities

of gas and oil have been obtained from the Brown sand zone at the top of the Fernie (Jurassic).

Palaeozoic Oils: The reservoir rock for the main production of crude oil in Turner Valley is from porous zones within the upper 450 feet of the Rundle limestone (Lower Carboniferous). In regard to a particular well, (Sioux City well in L.S.D. 16, sec. 1, tp. 20, range 3, west 5th Meridian), Campbell (11,p.34) has shown by analyses that limestone of a high magnesium content occurs toward the top of the Palaeozoic, while below the first 400 feet the limestone is dominantly calcium carbonate. The most productive zones appear to contain the greatest percentages of magnesium, with a general extremely low silica content for these porous zones. The occurrence and descriptions of the zones within the Rundle limestone, as derived from recent work by MacKenzie (32), are given below in descending order:

Upper Dense zone	About 100 feet of non-porous dark grey to buff limestone, occurring below the Palaeozoic-Mesozoic unconformity. Top 10 feet may be porous. In the northern half of Turner Valley an irregular porous band occurs 60 feet below top of limestone.

(continued)

Upper Porous zone	About 100 feet of highly dolomitized limestone. Porosity appears to decrease in southern half of the valley.
Middle Hard zone	About 60 feet of dense, hard, siliceous limestone with few chert bands. Very persistent zone.
Crystalline zone	Highly calcitic limestone. Zero to 70 feet thick in south end of valley, 150 feet thick in part of central area, and 60 feet thick in northern part of valley.
Lower Porous zone	General thickness 70 feet, apparently low porosity in north half of tp. 19.
Black lime	At least 800 feet of generally dense, none-porous, dark limestone.

The oil production in Turner Valley is chiefly from the Upper and Lower Porous zones. Since, in general, no casing is run through the producing limestone, it is difficult to know what amount of oil is obtained from the individual porous zones.

Source Beds:

The source rocks for Turner Valley oil are not known. In regard to the Palaeozoic crude, recent opinion favors a Palaeozoic source. MacKenzie (36,p.1626) writing in 1940, indicates a Palaeozoic source, and does not believe that any great migration of hydrocarbons took place vertically or laterally.

Previous to 1936 before the discovery of a Palaeozoic crude production in a deeper zone on the west flank, the Turner Valley limestone was believed to be a disconnected block (36, p.1423). At that time some theories attributed a Jurassic source for the Palaeozoic and for most of the Mesozoic oils (25, p.63). Goodman in 1935 (22, pp.249,250) had advocated a Palaeozoic origin for both the Palaeozoic and Mesozoic oils, and had based some evidence of a Palaeozoic source on the occurrence of bitumen and naphtha-laden gas in Palaeozoic rocks, and on the improbability of downward migration of oil through an impervious limestone, which apparently had been silicified before deposition of the Jurassic.

Properties of Oil*:

The gravities of oils from the Blairmore formation are as follows: 52.4 degrees A.P.I. for oils from the McDougall-Segur sand; 40.1 degrees A.P.I. for oils from the Home sand, and 50.2 degrees A.P.I. for oils from the Dalhousie sand. The gravity of the crude oil from the Palaeozoic limestone as shown from wells drilled within the last four years varies from approximately 38 degrees A.P.I. far down the west flank to about 54 degrees A.P.I. high up on the structure.

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*Source of data on properties of oil (14, 7, 73).

The sulphur content of the Turner Valley oils shows a marked difference with regard to the major reservoir rocks. The Mesozoic oils have a very low sulphur content, varying slightly for the different sands in the Blairmore formation, but averaging from about 0.10% to 0.15% by weight. The average sulphur content for the Palaeozoic crude oil as indicated by about 20 representative analyses, varies from 0.27% to 0.58% by weight, with an average of 0.44%.

The percent by weight of carbon residue in the Turner Valley Mesozoic oils is very small, varying for several analyses from 0% to 0.3%, with an average of 0.15%. For the Palaeozoic crude the carbon residue content as indicated from about 20 analyses ranges from 0.1% to 0.5 % with an average of 0.3%. The base of the Mesozoic oils is intermediate. The Palaeozoic crude oil has been classified as having an intermediate base, and containing wax in most cases.

Oils of Southern Alberta Plains Area:

Reservoir Beds:

Red Coulee: The commercial production of Red Coulee is from the Vanalta oil sand in the basal part of the Lower Cretaceous. The sand has an average thickness of 54 feet in Red Coulee and is comprised of fine to medium-grained loosely cemented quartz, and black chert sand (18,p.21). The greenish-grey shales and shaly limestones of the Ellis (Jurassic) occur below the oil sand, and red and greenish shales and sandstone occur above the oil sand. The Vanalta gas sand lies about 65 feet above the Vanalta oil sand (71, p.41). The lensy character of the oil sands is indicated by the occurrence of shaly bands within small lateral distances. Depths to the Vanalta oil sand in the Red Coulee field vary from 2,450 feet to 2,550 feet.

Del Bonita: The main known oil production reservoir in the Del Bonita structure is in the top zones of the Madison limestone within 80 feet of the Palaeozoic- Mesozoic contact. The rocks in this zone consist of grey limestone, which is cherty in places, and calcareous shale (51, p.2). Oil shows may occur in the sandy zones of the Lower Cretaceous about 200

feet above the top of the Ellis formation. The depth from the surface to the Madison limestone in the Del Bonita structure is from 5,000 feet to 5,200 feet.

Skiff: Oil has been produced in the Skiff area from sands in the Ellis (Jurassic) formation. The oil reservoir zone in a representative well lies about 50 feet above the Mississippian-Ellis unconformity. The reservoir zone consists of grey and green shales with limestone and sandstone (26, p.143). In one or two of the wells small shows of oil have been encountered in the Alberta shale and in beds of the Lower Cretaceous formation.

Taber: In the Taber structure some oil has been produced from the basal beds of the Lower Cretaceous (53, p.119). The oil sands have been indicated as being the equivalent of the Sunburst sand (7, p.81). The reservoir rocks are made up of light grey sandstones occurring at about 500 feet below the top of the Lower Cretaceous. The beds overlying the oil sand are grey, green and reddish shales. The description of the overlying beds and the position of the oil sand in relation to the overlying beds shows a marked similarity to the reservoir rocks and over-

lying rocks in Red Coulee. The elevation of the top of the Lower Cretaceous and the elevation of the oil sands in the Taber area are about 1,500 feet to 1,600 feet below the corresponding horizons in Red Coulee.

Source Beds :

Evans(18,p.12) has indicated the possibility of a Jurassic source for the oil in the Red Coulee structure. The Ellis (Jurassic) shows variations in lithology and thickness, so that although in parts of Montana it does not appear as a probable source rock for oil, yet in the southern Bearpaw Mountains, dark, petroliferous shaly limestones do occur. Two miles north of Red Coulee the Ellis is represented by greenish-grey shales, greenish sandstone, some black chert pebbles, and a little glauconite. However, in the producing area of Red Coulee the Ellis is not penetrated and Evans suggests the possibility that at the sites of the wells the character of the Ellis may be quite different (ibid., p. 12).

Sanderson (55,p.29) indicates the importance of the Ellis both as a source and reservoir for oil. Since the Palaeozoics in the Plains area show very little evidence as favorable source beds, Hume (25,p.65)

attributes a Jurassic source for the Lower Cretaceous and Jurassic oils of the Southern Alberta Plains. The Jurassic in the plains area is considered to thin out altogether about 100 miles north of the international boundary, therefore a Jurassic source is not believed applicable to the oils of central and northern plains of Alberta (ibid., p.63). Goodman (22, p.252) considers that in the plains area from Montana to McMurray, the oil and gas came originally from the Palaeozoics.

Properties of Southern Alberta Oils[x]:

The gravity of the Red Coulee oil averages about 31 degrees A.P.I., while in the Del Bonita area the oil is of about 36 degrees A.P.I. The Skiff structure produced oil of approximately 20 degrees A.P.I., while in the Taber field to the north of Skiff the gravity of the oil varies from 26 degrees A. P.I. to 29 degrees A.P.I. In the Steveville area the gravity of an oil from the Palaeozoic-Mesozoic contact is about 26 degrees A.P.I.

The sulphur percentages for representative

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[x] This data is from Dominion Analyses (48, chart), and F. K. Beach (7,73).

oils are:

Red Coulee Oil	1.2 %
Skiff	2.8 %
Taber	2.15%

The sulphur content of the Del Bonita oil is not known but is assumed quite high because oil shows from the Palaeozoic limestone in a Spring Coulee well are closely associated with sulphur water.

The carbon residue content for a Red Coulee oil is 2.5%; for Skiff oil, from about 8% to 10%; while for a Taber oil, 6.3%. The base of the above oils is given as Intermediate.

Oils of East Central Alberta Plains Area

Reservoir Beds:

The two main reservoir beds for gas and oil in this area are the sand in the basal part of the Upper Cretaceous and sandstone in the Lower Cretaceous (26, p. 202). The higher sands produce gas at Viking, and oil in the Fabyan and Wainwright folds. The productive sand in the Lower Cretaceous appears to be quite persistent in the Wainwright, Ribstone, and Lloydminster areas. This oil zone lies several feet below a coal seam that occurs from 130-165 feet below the top of the Lower Cretaceous. The oil sand appears to be generally fine-grained. Alternating

shale and sandstone beds are associated with the oil sand of the Lower Cretaceous, and indicate near shore conditions of deposition. The shales and sandstones of the Lower Cretaceous in East Central Alberta lack the variegated colors of the Lower Cretaceous in Southern Alberta. This factor suggests that in East Central Alberta area sub-aerial conditions prevailed when the Lower Cretaceous beds were being laid down (ibid. p. 216).

Source Beds:

Hume (ibid, p. 216) considers that the favorable source beds for the oil in the Wainwright-Ribstone area are the Lower Cretaceous beds in which these oils occur. Calder (74, p. 765) believes that for the Wainwright area there is sufficient information to postulate a theory to the effect that a vast underground seepage exists, but that there is insufficient pressure to force the oil to the surface. Calder does not suggest from what source the assumed seepage was derived. Goodman (22, p. 252) indicated that the oil and gas in the lower Mesozoics came originally from the underlying Palaeozoics, and that the small production could be attributed to structural conditions and possibly imperfect sealing.

Properties of Oil*:

The main oil production in the Wainwright-Lloydminster-Vermilion area is from a depth of 2,000 ± 250 feet. The gravities of the oil vary from approximately 12 to 20 degrees A.P.I. Lloydminster and Ribstone oils have gravities around 13° A.P.I., while in the Wainwright area the gravities range from about 14-20° A.P.I.

The sulphur content for Wainwright oils varies from about 2.5 to 3 percent. For Ribstone oils the sulphur content is about 3%, for Vermilion oils about 3 to 3.5%, and for a Lloydminster oil from 3 to 5 percent.

The carbon residue content of oils is from 6-8% for Wainwright oils; 9% for a Vermilion oil; 9-10% for Ribstone oils, and from 9-12% for Lloydminster oils. The base of most of the Wainwright oils has been classed as hybrid; i.e., naphthene base plus wax. The base of Lloydminster and Vermilion oils has been classed as naphthene.

Ultra-Violet Fluorescence of Oils:

General Remarks:

About 80 samples of crude oil, mainly from Alberta, were examined under the ultra-violet light A few tests were carried out to note what effect on

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*Source of above data is from (26, 48, 32, 73).

the fluorescence of oils was caused by time, by dilution of oil, by treatment with reagents, and by impregnation of sand with oil. The method of preparation and examination was standardized to the degree that:

(1) Samples of oil were prepared on one standard commercial filter paper;
(2) The samples were examined within four hours of preparation;
(3) Examinations were made in the ultra-violet light of a commercial lamp, series 370 of "Ultra-Violet" products Inc., shown in plate I;
(4) Examinations were made in a darkened room;
(5) Oil stains on the filter papers were examined by reference to control stains, i.e., when a series of examinations were being made, two sheets of oil stains were simultaneously under the ultra-violet lamp, so that after the completion of one sheet, another sheet of oil stains was substituted. In this manner comparison of fluorescence colors of the oil-stains could be made between different sheets.

The colors of the oils in daylight and under ultra-violet light were described from their visual appearance, and the colors denoted by approximate color and intensity adjectives. In regard to the color of the oils in daylight, both the colors in reflected and transmitted light were noted with the oil samples in standard size bottles, 6½" h. X app. 1¼" d. In the case of the dark brown or black oils the reflected colors were given. For the ultra-violet analysis it

PLATE I.

Figure 1: Ultra-violet lamp used for observing fluorescence of oil-stains. The two oil-impregnated filter papers under the lamp are in position for examination.

ULTRA-VIOLET LAMP

was not possible to set up any single oil sample as a basis for visual comparison of other samples. A grouping of the oils showing similar fluorescence colors and intensities facilitated the comparison and discussion of the fluorescence characteristics; but the necessity of an apparatus for determining the absolute colors and intensities of the fluorescence phenomena in oil was evident.

The chart (in pocket) lists the samples examined under the ultra-violet light. The date when the oil was bottled is indicated when known. In cases where the actual name of the well is confidential, only the geographical location is given. The information on the properties of the oils examined is shown as fully as data permit. In some cases the information is only approximately correct, i. e., in such cases where the analysis has been made at a different date than the sample was bottled. A few samples from areas outside of Alberta are included for comparative purposes. The first column in the chart indicates the reference numbers which were employed for denoting the oil samples:

T1, T2, T3, etc. - Mesozoic and Palaeozoic Turner Valley oils.

(continued)

F1, F2, F3, etc. - Oils from other locations of the Southern Alberta Foothills area.

S1, S2, S3, etc. - Oils from Southern Alberta Plains area.

C1, C2, C3, etc. - Oils from East Central Alberta Plains area.

1, 2, 3, etc. - Oils from other areas.

Fluorescence Color of Oils:

The fluorescence color of oil stains under the ultra-violet lamp ranged from non-visible to dark brown. In hardly any case did the fluorescence color and intensities of any two oils match, but very close agreements were observed among many samples. Plates II, III, IV indicate the appearance of some of the oil stains in daylight and under ultra-violet, as shown by the photographic plate. Small differences in the appearance of the stains in ultra-violet as compared to the appearance in natural light may be evident. It was not possible to obtain the correct relative exposure time for ultra-violet and daylight, so that the appearance of the stains may be misleading. Visually there was a great difference between the ultra-violet and daylight appearances of the oil stains, but since colors are not differentiated on the film, small distinctions only are evident.

PLATE II.

Figure 1: Photographs in daylight.

Photographs by daylight and ultra-violet light showing oil-stains of oils from various parts of Alberta.

Figure 2: Photographs in ultra-violet.

Oil Stains on Filter Paper
Daylight Photograph
Stained: 7/2/41.
Photographed: 23/2/41.

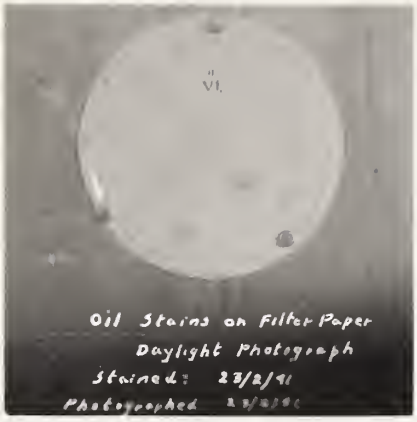
Oil Stains on Filter Paper
Ultra-Violet Photograph
Stained: 7/2/41.
Photographed 13/2/41

PLATE III.

Figure 1: Photograph by daylight.

Photographs by daylight and ultra-violet light showing oil-stains of various oils from Turner Valley.

Figure 2: Photograph by ultra-violet.


VI.
Oil Stains on Filter Paper
Daylight Photograph
Stained: 22/2/41
Photographed 22/2/41

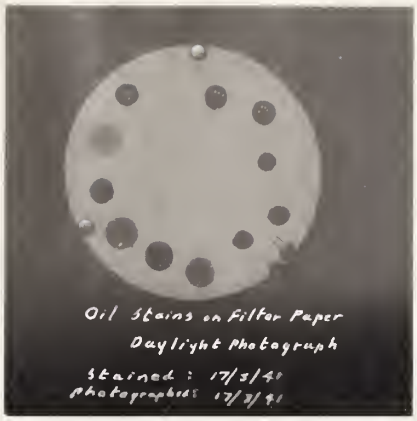
VI.
Oil Stains on Filter Paper
Ultra-Violet Photograph
Stained- 22/2/41
Photographed 22/2/41

PLATE IV.

Figure 1: Photograph by daylight

Photographs by daylight and ultra-violet light of oil-stains from oils of various parts of Alberta and Montana.

Figure 2: Photograph by ultra-violet


Oil Stains on Filter Paper
Daylight Photograph
Stained : 17/3/91
Photographed: 17/3/91

Oil Stains on Filter Paper
Ultra-Violet Photograph
Stained: 17/3/91.
Photographed: 17/3/91.

The description of the luminescence colors and intensities can probably best be given by employing separate groupings for oil stains showing similar luminescence. Reference numbers used indicate the samples and properties as shown on the chart (in pocket). For indicating a very small difference in visual appearance within a group (x) is appended to the sample number, while (i) indicates stains which are visually identical under the ultra-violet. It should be remembered that the white filter paper has a violet appearance under ultra-violet light.

Group I - samples showing no visible fluorescence. These oils were mainly highly volatile and light colored. The stains were examined directly after preparation.

T19	Gasoline from natural gas
T23	Casing head gas
T24	Turner Valley crude
4	Central Alberta foothills oil
5	Central Alberta foothills oil

Group II - samples showing very faint to faint fluorescence. The visual appearance of the stains in this group ranged from dull blue to grey.

T5	Turner Valley light crude
T16x	Turner Valley naphtha
F4x	Moose Mountain light crude
S1	Steveville naphtha
C5	Lloydminster seepage
9	Light diesel from McMurray sand.

Group III - Samples showing pale blue-grey to blue grey fluorescence:

T1x Turner Valley light crude
T2 Turner Valley light crude
T6 " " " "
T7 " " " "
T10 " " " "
T11x Turner Valley naphtha
T13x Turner Valley light crude (from separator)
T17 Turner Valley oil from relief line
T18 Turner Valley light crude
T28 Turner Valley light crude (from separator)

Group IV - Samples showing quite intense bluish-white fluorescence:

T4x Turner Valley light crude
T14x " " " "
T21x " " " "
T22x " " " "
T25(+yellow tinge) Turner Valley light crude
T26x " " " "
T27x " " " "
T28x " " " "
F3(+yellow tinge) Southern foothills light crude
F6x " " " "
1x " " " "
12x Pennsylvania crude

In this group the fluorescence colors were quite similar but small variations in color and intensity were present.

Group V - Samples showing clear yellowish-white fluorescence:

T3 Turner Valley light crude
T8 " " " "
T9(-yellow) " " " "

(continued)

T15x	Turner Valley light crude
T20x	" " " "
T25(-yellow)	" " " "
F1 (+grey)	Alderysde light crude
F2	Highwood light crude
S10i (+yellow	Del Bonita light crude (centrifuged)
S11i (+yellow)	Del Bonita light crude
S12i (+yellow)	Del Bonita light crude
8x	Oil from McMurray bituminous sand

Some samples may be repeated with modification in another group to show relation of certain color groups.

Group VI - Samples showing grey buff-yellow fluorescence:

S3 (darker)	Steveville light crude
S13i	Red Coulee light crude (top of tank)
S14i	" " " " (bottom " ")
13	Petrolia, Ont. crude.

Group VII - Samples showing bright buff-yellow:

S8x	Sunburst Mont., crude.
S10ix	Del Bonita light crude (centrifuged)
S11ix	Del Bonita light crude
S12ix	" " " "
S15x	Sunburst Mont. crude.
17x	Pouce Coupe light crude

The fluorescence colors of all these samples were very similar, while S10, S11, S12 from the same oil field were visually identical.

Group VIII - Samples showing buff brown fluorescence:

C6i	Wainwright heavy crude
C7x	" " "
C8	Vermilion heavy crude
C9i	Wainwright heavy crude
C10i	" " "
C11i	" " "
3x	Fort Norman, N.W.T., light crude

Group IX - Samples showing brown to dark brown fluorescence:

S5	Keho crude
S6	Taber heavy crude
C1x(dark)	Wainwright heavy crude
C2x(dark)	Vermilion heavy crude
C3x(dark)	" " "

Group X - Samples showing brown-black to black fluorescence:

S2	Taber heavy crude (from pool)
S4(black)	Skiff heavy crude
S7(black)	Taber heavy crude (dehydrated)
C4x	Lloydminster heavy crude
6x	Peace River heavy crude
14ix	" " " "
18ix	" " " "

Group XI - Samples showing distinctive fluorescence colors. Certain oil samples show odd or singular fluorescence colors and are described separately:

F7i	Oil City light crude
15i	Waterton lakes light crude

These oils fluoresced clear grey white against the violet background.

(continued)

T12 Alberta Pacific Cons. No. 1. Fluoresced a buff yellow color which did not resemble closely the fluorescence of any oil stain examined.

S9 Sweetgrass hills crude. Fluoresced a distinctive dark grass green color.

7 McMurray tar sand. The tar sand was exposed to ultra-violet but no fluorescence color was observed.

15 Windy Point (Great Slave Lake). Fluoresced a greenish buff-brown.

Related Fluorescence Tests:

Some of the samples examined for fluorescence had been kept for several years in sealed bottles, and it is not known what effect this time factor had on the fluorescence. The effect of time on the fluorescence of oil stains was demonstrated for some Alberta oils. Periodical comparisons of old stains were made with fresh stains of the same oils, and certain variations were observed. Samples prepared a few days apart visually showed very little fluorescent differences except in the case of light gravity oils where the stain had spread to a greater size and the clear cut peripheral rim had become less definite in outline.

With medium gravity oils the effect of time was similar to the above, although the peripheral rim as observed under ultra-violet was quite definite. The fluorescent color of the earlier prepared stain was visually identical to the freshly prepared stain, but the intensity appeared somewhat less. In regard to the heavy gravity oils the general reaction to time was a small increase in the size of the stain, and the development of a clear fluorescing narrow peripheral rim enveloping a darker fluorescing central portion. When the time between preparation of samples of the same oils was increased to a month the fluorescence similarities between stains of the same oil decreased proportionately. The light gravity oils maintained a fluorescence but showed a marked decrease of intensities and dulling or greying of fluorescence colors. The medium gravity oils showed similar decreases in intensities, though the fluorescence colors compared quite closely. In regard to the heavy gravity oils the fluorescence remained very similar, but the chief distinction between samples prepared at different times was the extensive development of a clear cut, light fluorescing peripheral band in the earlier prepared sample. The variation in width of the peripheral bands developed in three weeks, was

from about 0.5 mm. for Wainwright, Lloydminster, and Vermilion, to about 1 to 2 mm. for oils of Skiff and Taber. These bands were visually evident on the dark fluorescing stains in figure 2, Plate II, but the photograph does not show them.

The variation caused by concentration of a non-fluorescing oil with a dark fluorescing oil is indicated in Plate V. A dark brown fluorescing oil from Lloydminster Royalties No. 1 was added drop by drop to 1/4 test-tube of Royalite No. 27 naphtha. The fluorescent colors graded from a light buff color, when one drop of the Lloydminster oil had been added, through darker buff, brown, and dark brown. The addition of 10 drops of Lloydminster oilnto 1/4 test tube of the Royalite naphtha gave a fluorescence very similar to that of the undiluted Lloydminster oil. A McMurray bituminous sand sample did not exhibit any visible fluorescence but when a portion of the oil was extracted by the Royalite No. 27 naphtha, the latter, when observed on filter paper under ultra-violet light gave out a fluorescence very similar to that of one of the diluted Lloydminster oil stains.

Samples of the apparently non-fluorescing Royalite No. 27 naphtha were treated with concentrated

PLATE V.

Figure 1: Photograph in daylight.

Photographs by daylight and ultra-violet light showing concentration of a non-fluorescent naphtha with a fluorescing crude.

Figure 2: Photograph in ultra-violet.

Oil Stains on Filter Paper
Daylight Photograph.

Oil Stains on Filter Paper
Ultra-Violet Photograph
Stained: 27/2/41.
Photographed: 2/3/41.

sulphuric acid, concentrated nitric acid and powdered sulphur. In no case was any fluorescence induced.

An oil-impregnated core sample from Wainwright Petroleum well from a depth of 2,249 feet exhibited a very poor dark brown fluorescence. Fluorescent oils applied to surface sand showed out much the same as on filter paper.

Discussion of Fluorescence Properties:

Variation of Color of Oil with Fluorescence:

In all cases observed where no fluorescence occurred, the colors of the oils by reflected natural light, as observed in the sample bottles, were water clear to straw yellow. Oils which fluoresce very faintly to faintly in ultra-violet light, were with one exception, very pale straw to straw color in reflected light. For the oils which showed a blue-grey fluorescence in ultra-violet, the color range in daylight was given as amber to dark red for transmitted and yellow-green to dark green for reflected light. Samples exhibiting intense bluish-white fluorescence show mainly red to dark red in transmitted light, and yellow-green to green in reflected light. Oils of yellowish-white fluorescence, exhibit in most cases dark red color for transmitted light, and dark green

to very dark green for reflected light. Oils of groups VI, VII, above, which had buff-yellow fluorescence, were too dark to transmit light through the thickness of the standard size bottle used. In reflected light the colors varied from brownish-green to very dark green. Oil showing buff-brown to brown-black fluorescence appeared black in reflected light. In all but two cases the converse was also true. Oils from Windy Point on the north shore of Great Slave Lake, and Sweetgrass Hills, Montana, appeared quite black in reflected light but fluoresced respectively, a greenish buff-brown, and a distinctive dark grass green. From the above evidence it appears that with few exceptions, a definite trend is indicated between the color of crude oil in daylight, and the fluorescent color in ultra-violet light.

In regard to refined and distilled oils, some interesting observations were noted. Samples of the first, second, and third fractions of a gas oil showed respectively, pale straw, light brown, and brown reflected colors, but did not exhibit any visible fluorescence. A non-viscous lubricating oil which was red by transmitted light and brown by reflected light, showed only a very faint bluish fluorescence under the ultra-violet. A medium lubricating oil which was

a deep red in transmitted light and a dark brown in reflected light, showed only a faint fluorescence under ultra-violet light. The source oil of the above fractions was not known, but from a consideration of the results it would appear that in regard to light gravity fractions, the color and fluorescence do not show the relation that apparently exists in light gravity crude oils. On the other hand, a crude distillate from the McMurray bituminous sands gave a fluorescence very nearly identical with that of a crude oil from Del Bonita. These two oils were of a similar dark green color by reflected light and appeared to be of a similar gravity. Outside of these few instances the examination in fluorescence for processed oil was not made. Bentz and Strobel (9, p. 334) state that for German oils, refined oil could be easily distinguished from crude oil by the lack of, or difference in fluorescence of the refined oil. For Alberta oils this may be true of crude and refined oil from one area by apparently does not hold in all cases.

Comparison of Gravity of Oil and Fluorescence:

In most cases an increase in gravity appears to be associated with a change in the natural color of the crude oil, so that it is difficult to know just

what is the net variation of fluorescence with gravity. In the samples examined the following results were indicated. The gravities of oils which showed no visible fluorescence ranged between 55° and 70° A.P.I. The gravities of Royalite No. 4 casing head gasoline, and of a gasoline from Turner Valley natural gas were not determined, but were definitely above the 55° A.P.I. The gravities of oils which showed faint fluorescence were between 48 and 62 degrees A.P.I., with one exception which had a gravity of 31° A.P.I. and proved to be a refined oil. About 20 oils which exhibited pale blue-grey to intense blue-white fluorescence had gravities between 40 and 60 degrees A.P.I. Oils showing a clear yellowish-white fluorescence had gravities mainly between 36 and 46 degrees A.P.I. while oils showing buff-yellow fluorescence had gravities from 31 to 36.4 degrees A.P.I. The gravities of oils showing buff-brown to dark brown fluorescence varied between 14.5 and 19 degrees A.P.I. Two exceptions were noted here, Plains Pet. No. 2, with a reported gravity of 26° A.P.I., and Fort Norman oil with a gravity of around 32° A.P.I. Gravities of oils exhibiting brown-black fluorescence, to black color without any apparent fluorescence, ranged from 12 to 20 degrees A.P.I.

From a comparison of gravity and fluorescence a certain general trend is apparent. No fluorescence was observed for oils lighter than 62 degrees A.P.I. For Alberta oils fluorescing respectively, faint violet, pale blue-grey, quite intense bluish-white, clear yellowish-white, buff-yellow, buff-brown, brown-black, the gravities showed rather irregular decreases, from 62 degrees for a very faint fluorescing oil, to 12° A.P.I. for a dark-brown fluorescing oil.

It appears that a change in A.P.I. gravity of crude oil is generally accompanied by a change in the natural color of the oil, and it has been shown above for Alberta oils that there is, in general, a relationship between the color and fluorescence in crude oil. Therefore, if it were possible to keep the color of the oil constant, with varying gravity, one might determine the net relation or effect of gravity of oil with color of fluorescence.

It has been shown that in the case of processed oils where a distilled oil had similar color and gravity to a crude oil, nearly identical fluorescent colors resulted; but when the distilled oil showed only a faint stain on filter paper, even though the gravity was as low as 31° A.P.I., the fluorescence color was

similar to the fluorescence color of a light gravity crude.

The relationship between fluorescence and gravity may be indicated from some Palaeozoic oil samples from Turner Valley. In the case of four samples with gravities of 54.8, 50, 46.1, and 43 degrees A.P.I. the transmitted and reflected colors in natural light appeared very similar. When subjected to ultra-violet light the fluorescent colors were very similar in all the oil stains, but the intensity of the color appeared to increase progressively as the A.P.I. gravity varied from 54.8 to 43 degrees. The variation of gravity of nearly 12 degrees A.P.I., without any marked difference in fluorescence color would indicate to the writer that the gravity of an oil cannot be predicted from the color of the ultra-violet fluorescence. If intensity and color were objectively measured it may be possible to determine the gravity of oils producing from the same reservoir beds.

Variations of Fluorescence with Age of Reservoir Beds:

The general association of color, fluorescence, and gravity of oils has been indicated above, and for this reason it would be difficult to know what variation,

if any, could be attributed to reservoir beds. The fluorescence of oils with age of reservoir beds is given in order of increasing age. The Lower Cretaceous oils of the East Central Alberta Plains area generally fluoresced brown, but showed small variations in shade. These oils were quite black in reflected light and of low A.P.I. gravities. The Lower Cretaceous of the Southern Alberta Plains area fluoresced from buff-yellow to dark-brown. The Red Coulee oils of Lower Cretaceous age emitted a fluorescence color quite similar to that of a Palaeozoic oil show from Steveville, and a Devonian oil from Ontario. The Lower Cretaceous oils of Turner Valley exhibited fluorescence colors similar to those of the Turner Valley Palaeozoic oils of related colors and gravities. The sample of Jurassic oil from Skiff was rather peculiar in that it exhibited a pitch black color by reflected light and no apparent fluorescence in ultra-violet light. The Del Bonita crude oil from reservoir beds of Mississippian age fluoresced very much like a Triassic oil from Pouce Coupe and like two Sunburst, Montana, oils of unknown age. In all cases mentioned above the colors and gravities of oils showing similar fluorescence in ultra-violet light were closely related.

A few samples examined did not appear to follow the general trend. A sample of oil from Sweetgrass Hills of medium gravity and a black color in reflected light exhibited a singular dark grass green fluorescence color not encountered in any other oil examined. The age of the reservoir beds are not known. Samples from the old Lineham and Oil City wells in Waterton Park fluoresced a distinctive grey white, not duplicated in any sample examined. The reservoir beds are considered Cretaceous in age (26, p. 79). The color and gravity were very close to those of Del Bonita oil. It is not known what factors modified the fluorescences in these cases.

It must be concluded that considering the above cases, fluorescence of oils cannot be used in Alberta for correlating ages of reservoir beds.

Discussion of Other Properties:

Variation of Gravity with Elevation of Reservoir Beds:

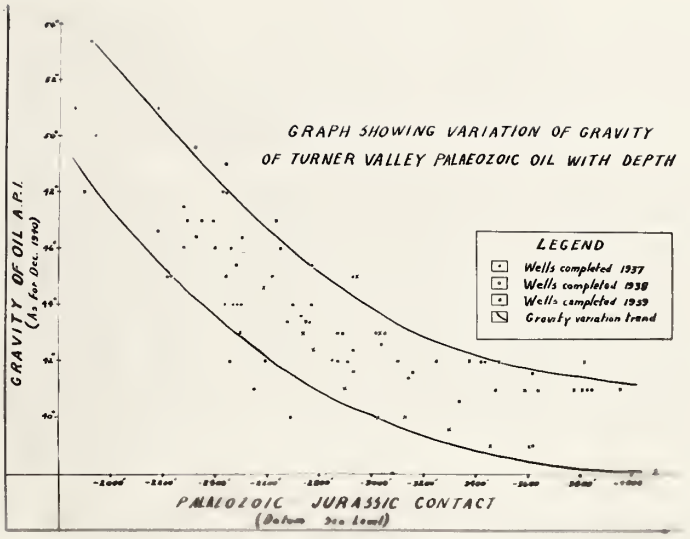
A very apparent relationship exists for Turner Valley Palaeozoic oil, between gravity of the oil and elevations of the producing horizons. Since the oil from the Palaeozoic lime may come from as many as three porous zones, the gravity figures would indicate average gravity for oil from zones separated by as

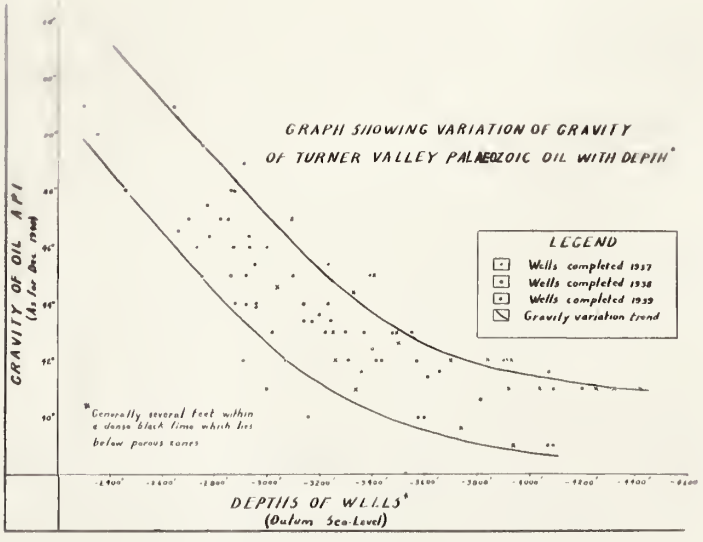
much as 300 feet. The changes in gravity with elevations of certain horizons were plotted and are shown graphically in Plate VI. The data is from about 85 wells completed from 1937-1939 inclusive. In figure 1, Plate VI, the gravities were plotted against the elevations of the Palaeozoic-Mesozoic contact, which is an erosional contact. In figure 2, Plate VI, the gravities were plotted against the elevations of the bottom of completed wells. The wells were generally drilled from 10 to 20 feet into the Black lime occurring below the Lower Porous zone. Thus the bottom of completed holes indicates a stratigraphical horizon while the Palaeozoic-Mesozoic contact is an erosional horizon. The graphs indicate that a decrease in A.P.I. gravity, with decrease in elevation of the erosional horizon and of the stratigraphical horizon is quite regular, but that there is distinctly less scattering of plotted points in the case where elevations of the Black lime were used. The average decrease in gravity with elevation is about one degree A.P.I. per 150 feet down structure. This variation is about two to three times greater than that for the Lower Light Oil zone (lower Pliocene) of the Ventura Avenue field in California. This California field has a reported

PLATE VI.

Figure 1: Graph showing variation of gravity of Turner Valley oil with variation of elevation of Paleozoic-Mesozoic contact.

Figure 2: Graph showing variation of gravity of Turner Valley oil with variation of elevation of Black Lime zone.


GRAPH SHOWING VARIATION OF GRAVITY
OF TURNER VALLEY PALAEOZOIC OIL WITH DEPTH
LEGEND
Wells completed 1937
Wells completed 1938
Wells completed 1939
Gravity variation trend
GRAVITY OF OIL A.P.I.
(As for Dec. 1940)
PALAEOZOIC JURASSIC CONTACT
(Datum Sea Level)


GRAPH SHOWING VARIATION OF GRAVITY
OF TURNER VALLEY PALAEOZOIC OIL WITH DEPTH*
LEGEND
Wells completed 1937
Wells completed 1938
Wells completed 1939
Gravity variation trend
GRAVITY OF OIL API
(As for Dec. 1940)
*Generally several feet within a dense black lime which lies below porous zones
DEPTHS OF WELLS*
(Datum Sea-Level)

productive closure of 1,200 feet and is cited as an ideal example for illustrating completely sealed, closed domal structures (Taff, p. 209).

In regard to the productive domes and noses in the Southern Alberta Plains, and the productive folds in the East Central Plains area, there are too few oil wells and too small closures to permit a plotting of the gravity-elevation trends.

Variation of Gravity of Alberta Oils with Age of Reservoir beds:

In regard to three areas of Alberta, Turner Valley, Del Bonita, and Steveville, where there occur Lower Carboniferous oil reservoir beds, the gravities of the oils differ widely. The order of decreasing A.P.I. gravity for oils of somewhat similar age reservoir beds, is Turner Valley, Del Bonita, Steveville. It would seem that the age of reservoir beds is not the factor determining the gravity of the oils. The intense thrust faulting in Turner Valley has been thought to be associated with the high gravity of the Turner Valley naphtha (6, p. 161). Working on this hypothesis one might suggest that evidence appears to indicate that higher A.P.I. gravities occur in proximity to regions of past intense diastrophic movements. Considering the oils from the three areas above, and from reservoir

beds of similar age, the decrease of A.P.I. gravity with increased distance from areas of major orogeny, seems to be borne out. Other factors such as source materials, chemical reactions, and depth have undoubtedly modified the gravities of the oil of the three areas.

In regard to the Mesozoic oils of the areas investigated, the A.P.I. gravities in the main are heavier than those of Palaeozoic oils. One exception to this rule are the Mesozoic oils of the Southern Alberta foothills area. The general trend, of decrease in A.P.I. gravity with increase in distance from areas of major diastrophism, appears evident for the Mesozoic oils studied. The gravity for oils from Lower Cretaceous reservoir beds shows a decrease in A.P.I. gravity from Turner Valley, where the structure is highly folded and faulted; to Red Coulee, where the structure is a plunging nose on the northwest flank of the Sweetgrass arch; to Taber where the structure is less pronounced; to East Central Alberta, where structures consist of minor folds on a gentle regional arch. The reservoir beds for the Skiff oil are Jurassic, and the gravity of 20° A.P.I. appears in this case at variance with the general trends of increase in A.P.I. gravity with increasing age, and decrease of A.P.I. gravity with

distance from areas of major movement.

No doubt other factors such as source materials, chemical reactions, depths, and local structures must be considered in an evaluation of the gravity-age relation of Alberta oils.

Variations of Other Properties of Oil with Age of Reservoir Beds:

Sulphur: The Turner Valley Palaeozoic oils have a relatively low sulphur content, (average 0.44%), but show marked variation for different wells. No data were available on the sulphur content of Palaeozoic oils from Del Bonita and Steveville. In regard to Mesozoic oils, the Turner Valley oils were unique for their abnormally low sulphur content. It should be noted that the content varies for oil from one oil zone, but the average sulphur content for the oil from the Blairmore formation is probably very near the average content of sulphur for any of the three productive sands in the Blairmore formation. In the plains area the sulphur in Lower Cretaceous oils of southern Alberta varies from about 1 to 2.5%, while the variation in content for East Central Alberta is from about 2.5 to 5%. From the few data available it would appear that the sulphur content may vary a little between reservoir beds of some folds, as for instance between the Battleview-

Wainwright fold and the minor fold near Lloydminster. In these cases where the reservoir beds are the same age, there appears to be an increase in sulphur content with decrease in A.P.I. gravity. The trend of increase in sulphur content with decrease in A.P.I. gravity seems to be followed quite closely when the Lower Cretaceous oils of Southern and East Central Alberta plains are compared.

Bartram (5, p. 131) mentions that for the Tertiary Gulf Coast crude oils of United States a normal decrease of sulphur has been shown to occur from Miocene to Eocene sands, and with increase depth. In the Alberta areas studied it is hardly possible to make such a comparison except for Turner Valley. In this case it is evident that the sulphur content is higher in the Palaeozoic than in the Lower Cretaceous.

Carbon Residue and Base of Oil: The residuum in Turner Valley Palaeozoic crude increases in amount with decrease of A.P.I. gravity. The data on carbon residue for Alberta oils are quite scarce, but the trend for the Lower Cretaceous oils of the plains area seems to be an increase in percent carbon residue with decrease of A.P.I. gravity. It is generally assumed (48, p. 11) that the carbon residue of crude oil is

about proportionate to the amount of asphalt dissolved in the crude. On that basis it may be stated that for the Lower Cretaceous oils of the plains, the asphaltic character increases from the southern plains to the northern plains.

The character of the base for the Lower Cretaceous oils of the plains is from an intermediate-base for Southern Alberta oils to hybrid - or naphthene - base for East Central Alberta oils. Both the Mesozoic and Palaeozoic oils of the Southern foothills have mainly an intermediate base. Barton (4, p. 145) has shown that the character of United States crude oils trends from naphthenic for young; from intermediate toward naphthenic for middle-age oils; and from intermediate toward paraffinic for old-age oils. In the Alberta areas considered, the character of the base of oil does not appear related as much to age of reservoir beds as to the structure in these areas.

C H A P T E R V

SUMMARY AND CONCLUSIONS

The study of oils was limited to those of the Southern Alberta Foothills area, the Southern Alberta Plains area, and the East Central Alberta Plains area. Stratigraphy and structure of the areas were discussed with relation to oil occurrences. The properties of oil dealt with were gravity, sulphur content, carbon residue, base of oil, color, and ultra-violet fluorescence. The variations of the first four mentioned properties with reservoir beds were indicated for Alberta oils, and for some United States oils. The ultra-violet fluorescence of oils constituted the major investigation carried out by the writer. About 80 samples of crude oil were examined under the ultra-violet light. Most of the oil samples examined were from the oil areas of Alberta indicated above; eight samples were from other areas of Alberta, while three samples were from other parts of Canada, and four samples were from the United States. The list of oil samples, together with their properties, is shown on a chart (in pocket).

The procedure followed in the ultra-violet

examinations consisted in permitting a drop of oil on filter paper to spread by capillary action, and examining the oil stain under ultra-violet light. The evaluation of fluorescence colors and intensities was by visually comparing the different samples under the ultra-violet light.

From the investigation of some Alberta oils in ultra-violet light certain results and conclusions were arrived at:

First, a relation is indicated between the color of crude oils in daylight and the color of the oil in ultra-violet light. A light colored oil may exhibit a light blue or yellow fluorescence; darker oil in most cases showed brown fluorescence, while black oils showed either dark brown fluorescence or no fluorescence. Exceptions to the general trend were observed in a few cases.

Second, the writer does not believe that fluorescence can be used to distinguish refined oils from crude oils. Although in some cases refined oils fluoresced differently from crude oils, yet in one case a distilled oil from one area of Alberta exhibited nearly identical fluorescence to a crude oil from another part of Alberta.

Third, in all the oils examined the ~~upper~~ lower limit of gravity of oils showing no visible fluorescence was 62° A.P.I., ~~and the lower limit was 55° A.P.I.~~ Oils of gravities between ~~these limits~~ 62° and 55° A.P.I. may or may not fluoresce. In the case of oils from the same reservoir bed a variation in gravity of nearly 12° A.P.I. had very little effect on the fluorescence color. In this case an intensity increase, with decrease in A.P.I. gravity, appeared to exist. Considering the above evidence, it seems unlikely that the gravity of an oil can be predicted from the color of ultra-violet fluorescence.

Fourth, in regard to ultra-violet fluorescence of oil and reservoir beds, samples from the same age reservoir rock may show similar fluorescence. But three samples of oils from Alberta which exhibited nearly identical fluorescence were a Triassic crude, a Lower Carboniferous crude, and an oil distilled from a Lower Cretaceous crude. Therefore the writer is forced to the conclusion that fluorescence in oils cannot be relied on for indicating the age of reservoir beds.

The variations in gravity, sulphur content, carbon residue, and base of oils, with reservoir beds,

were noted for some Alberta oils. The variation in gravity with elevation of the Palaeozoic reservoir beds of Turner Valley was about 1° A.P.I. decrease per 150 feet down structure. No regular trend appeared to exist between the gravity of Alberta oils and age of reservoir beds, but a relationship was indicated between the gravity of oils and structure of reservoir beds.

The sulphur content of the Lower Cretaceous oils of the plains area showed in general, an increase, with decrease in A.P.I. gravity. For Turner Valley oils the sulphur content of the Palaeozoic oils was greater than that of the Mesozoic oils. The data on carbon residue content of Alberta oils are too few to indicate the variation of carbon residue with age of reservoir beds. From a consideration of the variation in the base of oils with age of reservoir beds, it appears that the character of the base of oil is not related as much to the age, as to the structure of the the reservoir beds.

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Chart Showing Properties of Some

Ref. No.	Date Sampled	Location	Well and Number		Color: Transmitted	Color: Reflected	Ultra-Violet Fluorescence Color	Depth to Oil Sand	A.P.I. Grav. of Oil	Sulphur %
		SOUTHERN FOOTHILLS AREA:								
		Turner Valley:	(a) Mesozoic:							
T 1		Turner Valley	Dalhousie	5	Dark red	Dark green	Pale blue-grey	4810	51	(0.45)
T 2		" "	Home	192	Dark red	Dark green	Pale blue-grey like T1	4560-4807	(40)	(0.09)
T 3		" "	Home	6	Orange red (cloudy)	Dark green	yellowish-white	4687	38.8	
T 4		" "	McLeod	1	Red	Dark green	Bluish white (yellowish), like T 27	2390	54.6	
T 5	1926	" "	McLeod	2	Very pale straw	Very pale straw	Faint yellow grey	3360	58.8	
T 6		" "	Royalite	15	Orange red	Light brown	Blue-grey like T1, (greyer)	3003-35	50.8	
T 7		" "	United	4	Red	Brownish-green	Blue-grey like T1	5567	41.0	
T 8		" "	Vulcan	3	Brownish red	Dark brownish-green	Yellowish-white	3033	40.4	
T 9		" "	Vulcan Oils Co. Ltd.		Red (cloudy)	Dark green	Yellowish white lighter than T3		46	
T 10		" "	Widney	1	Brown-red	Brown black	Blue-grey	4710	49.8	
			(b) Palaeozoic:							
T 11	1937	Turner Valley	Anaconda	2	Amber	Yellowish-green	Dull bluish-white like T1	5518	60	0.34
" 12		" "	Alberta Pacific Cons.	1		Dark brown black	Buff yellow			
" 13	1937	" "	B. & B. (separator)		Red	Green	Light blue like T17	(6609)	48.4	
" 14	1937	" "	Century Royalties	1	Orange-red	Yellowish-green	Bluish-white	6535	54.8	0.43
" 15	1939	" "	Coronation	1	Dark red	Green	Yellowish-white	7572	43	0.45
" 16	1937	" "	Foothills	1	Amber	Light brown	Faint blue	5914	62	
" 17	1936	" "	Foundation	1 (Relief line)	Red	Green	Pale blue between T1 & T18			
" 18		" "	Foundation crude		Amber	Yellowish-green	Light blue	6474	49.5	
" 19		" "	(Gasoline from natural gas)		Straw color	Straw color	No visible luminescence			
" 20	1939	" "	Home-Mollerville	2	Dark red	Green	Clear yellowish-white like 2	8480	39.0	
" 21	1937	" "	Model	1	Red	Green	Light bluish-white		43.0	0.44
" 22	1938	" "	Model-Spooner Reward	1	Orange-red	Light green	Light bluish white	6942	50.0	0.47
" 23		" "	Royalite (casing head gas)	4	Straw color	Straw color	No visible luminescence			
" 24	1937	" "	Royalite	27	Water clear	Water clear	No visible luminescence	5570	70.2	
" 25	1936	" "	Sunset	1	Dark red	Green	Bluish-white, yellowish tinge	7475	41.6	
" 26	1937	" "	Turner Valley Royalties	1	Dark red	Green	Bluish-white	6828	46.1	0.30
" 27	1938	" "	Westside Royalties	1	Amber	yellowish-green	Bluish-white (Flaxflower blue of Ridgway)	6374	53	
" 28	1937	" "	Westside Royalties (from separator)	1	Orange red	Clear green	Bluish-white (Flaxflower blue of Ridgway)		49	
		OTHER AREAS IN SOUTHERN FOOTHILLS:								
F 1	1939	Aldersyde				Dark brownish green	Yellowish-white, duller than 2		30.2	
F 2	1938	Highwood				Dark green	Yellowish-white	5730	39.7	
F 3	1938	Southern Foothills			Orange red	Light green	Bluish-white like T 27, but yellower	7013	37.1	
F 4	1938	Moose Mountain			Straw yellow	Straw yellow	Faint light blue		48.3	
F 5	1936	Aldersyde	New Valley	1	Dark red	Dark green	Yellowish white similar to T3	6530	38.	(0.12)
F 6	1937	Southern Foothills	Weymarn-Pincher Creek	2	Dark red	Green	Bluish-white like T 27	6260	40.1	
F 7		Oil City				Dark green	Clear grey white like 16		38.3	
		SOUTHERN ALBERTA PLAINS AREA								
S 1	1939	Steveville			Pale straw	Pale straw	Very faint dull blue, invisible under one window pane		62.6	
S 2	1940	Taber	Border Peke (from pool)	1		Black	Heavy brown black like Skiff			
S 3	1940	Steveville				Brown black	Buff yellow brown, darker than S13	4085-4120	31.4	
S 4		Skiff	Devenish	1		Black	Black	3690	19.0	2.8
S 5	1939	Stobby Butte (Keho)	Hudson Bay Keho	1		Black	Medium dark brown			
S 6	1940	Taber	Plains Pet.	2		Black	Brown with lighter peripheral rim	3218	26.1	(2.15)
S 7	1937	Taber	Plains Pet. (dehydrated)	3		Black	Black, darker than C2, C3	3239	12.3	
S 8		Toole County, Montana	Sunburst	1		Very dark green	Bright buff yellow, like S10, S11			
S 9		Sweet Grass Hills				Black	Distinct grass green, greyer towards periphery			
S 10	1939	Del Bonita	Terminal (centrifuged)	1		Dark green	Bright buff yellow like F2	(7800)	33.6	
S 11	1939	Del Bonita	Terminal	2		Dark	[illegible]			

Some Oils

d	A.P.I. Grav. of Oil	Sulphur %	Carbon Residue	Base of Oil	Formation or Sand
	37	(0.15)	0.2	Intermediate	Dalhousie Sand
7	(46)	(0.09)	0.2	"	Home Sand
	38.8			"	Home Sand
	54.6			"	Mc Dougall-Segur Sand
	58.3			"	Dalhousie Sand
	50.8			"	Blairmore Formation
	41.0			"	Dalhousie Sand
	40.4			"	900 feet below top of Blairmore
	46			"	Below top of Blairmore
	49.8			"	Dalhousie
	60	0.34	0.04	Intermediate	Rundle Limestone ?
	48.4			Intermediate	Rundle Limestone
	54.8	0.43	0.2	"	" "
	43	0.45	0.5	"	" "
	62			"	" "
				"	
	49.5			"	Rundle Limestone
				"	"
	39.0			"	"
	43.0	0.44	0.2	"	"
	50.0	0.47	0.2	"	"
				"	"
	70.2			"	"
	41.6			"	"
	46.1	0.30	0.3	"	"
	53			"	"
	49			"	"
	30.2				Oil show
	39.7				" "
	37.1				" "
	48.3				
	38	(0.12)	(0.5)	Paraffin	Show in Upper Cardium
	40.1				Oil show
	38.3				
	62.6				Oil show
o	31.4				Oil show
	19.0	2.8	9.8	Intermediate	Ellis, Jurassic
	26.4	(2.15)	(6.3)	"	Sunburst equivalent, L. Cret.
	17.3				L. Cretaceous
					L. Cretaceous
	35.6			"	Sunburst Sand L Cret.

SOUTHERN ALBERTA PLAINS AREA												
S	1	1939	Steveville			Pale straw		Pale straw		Very faint dull blue, invisible under one window paper		62.6
S	2	1940	Taber	Border Pete (from paul)	1			Black		Heavy brown black like S13		
S	3	1940	Steveville					Brown black		Buff yellow brown, darker than S13	4085-4120	31.4
S	4		Skiff	Devenish	1			Black		Black	3090	19.0
S	5	1934	Scobby Butte (Keho)	Hudson Bay Keho	1			Black		Medium dark brown		
S	6	1940	Taber	Plains Pet.	2			Black		Brown with lighter peripheral rim	3248	26.1
S	7	1937	Taber	Plains Pet. (dehydrated)	3			Black		Black, darker than C2, C3	3239	17.3
S	8		Toole County, Montana	Sunburst	1			Very dark green		Bright buff yellow, like S10, S11		
S	9		Sweet Grass Hills					Black		Distinct grass green, greyer towards periphery		
S	10	1939	Del Bonita	Terminal (centrifuged)	1			Dark green		Bright buff yellow like F2	(4800)	35.6
S	11	1939	Del Bonita	Terminal	2			Dark green		Bright buff yellow	5200	36.1
S	12	1940	Del Bonita	Terminal	2			Dark green		Bright buff yellow	5200	36.0
S	13	1940	Red Coulee	Vanalta	1,2,4			Very dark green		Grey buff yellow, darker than S10, S11	2490-2490	31
S	14	1940	Red Coulee	Vanalta	1,2,4			Very dark green		" " " " " "	" "	
S	15		Sunburst, Montana	Gladys Belle				Dark green		Bright buff yellow, like S8		
EAST CENTRAL ALBERTA PLAINS AREA:												
C	1	1914	Wainright	British Petroleum	4			Black		Dark brown, like C2	2025-36	14.5
C	2	1940	Vermilion					Black		Dark brown		14.3
C	3	1940	Vermilion					Black		Dark brown, lighter than C2 (Cinnamon brown-Ridgway)	1842-58	14.8
C	4	1939	Lloydminster	Lloyd. Royalties	1			Black		Dark brown-black, like 6	1922	12.4
C	5	1926	Lloydminster	Lloydminster (see page)		Straw		Straw		Very faint		36.5
C	6		Wainright	British Pet. Ltd.				Black		Buff brown, like C8	2259	18.0
C	7		Wainright	Wainright Pet. Ltd.				Black		Buff brown	2252	18.1
C	8		Vermilion	West Battleview	1			Black		Buff brown, distinct rim	1835	15.4
C	9		Wainright	Edmonton-Wainright Co. Ltd.				Black		Buff brown, like C8	2238	19.1
C	10	1930	Wainright	Onalta				Black		" " " "	(2232)	22.0
C	11		Wainright	Bellwain	2			Black		" " " "	(2286)	
OTHER AREAS:												
	1	1940	Pincher Creek			Red		Green		Bluish-white, like T27	4777-4836	40.6
	2	1939	Central Alberta Foothills			Dark red		Dark green		Yellowish more yellow than F2		38.9
	3		Fort Norman							Light brown, similar to C7	2607	32
	4	1940	Central Alberta Foothills			Very pale straw		Very pale straw		No visible luminescence		55.2
	5	1940	" " "			Water clear		Water clear		No visible luminescence		64.9
	6	1916	Peace River	McArthur	2			Black		Dark brown-black like S2		12.7
	7		McMurray	McMurray Tar Sand				Black				
	8		"	McMurray oil, from bituminous sand				Dark green		Lemon yellow, like T20		
	9		"	" " , light diesel		Dark amber		Reddish brown		Very faint		31.0
	10		"	" " heavy diesel				Brownish black		Greyish-blue, distinctive		24.0
	11		Peace River	Below Peace River Crossing				Black		Black, lighter than 6		
	12		Pennsylvania	West Pennsylvania crude		Red		Green		Bluish-white		
	13		Ontario	Petrolia crude, Ont.				Brownish black		Bright buff, like S3		34.0
	14	1916	Peace River	McArthur	1					Very dark brown		
	15		Waterton Lakes	Lineham well						Clear grey white, like F7	1020	38.3
	16		Windy Point (Ct. Slave Lake)							Greenish buff brown		
	17	1940	Peace Coupe					Dark green		Bright buff yellow similar to S12		36.4
	18		Peace River	Peace River Oil Co.	2					Very dark brown, equal to 14	1000±	12.0

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38.3				
62.6				Oil show
31.4				Oil show
19.0	2.8	9.8	Intermediate	Ellis, Jurassic
26.1	(2.15)	(6.3)	"	Sunburst equivalent, L. Cret.
17.3				L. Cretaceous
				L. Cretaceous
35.6			"	Sunburst Sand, L. Cret.
36.1				Madison Limestone
36.0				" "
31	(1.2)	(2.4)	"	Vanalta Sand, L. Cret.
	"	"	"	" " " "
14.5	(2.6)	7.7	Hybrid	
14.5				Oil show
14.8	3.4	9.2	Naphthene	
12.4	3.9	11.7	Naphthene	L. Cretaceous
56.5				
18.0				L. Cretaceous
18.1				L. Cretaceous
15.4				
19.1				L. Cretaceous
22.0				L. Cretaceous
				L. Cretaceous
40.6				Oil show
38.9			Intermediate	Oil show
32	(0.38)	(1.8)	Intermediate	Fort Creek, U. Devonian
55.2	(0.02)		Paraffin	Oil show
64.0				Oil show
12?	(4.9)			L. Cretaceous
	5.4	(19)	Naphthene	McMurray Fm., L. Cretaceous
31.0				
24.0				
				L. Cretaceous
34.0	(0.8)	(2.1)	Intermediate	Onondaga, M. Devonian
38.3				
36.4	(0.56)			Colite(?), Triassic
12.0				Loon River Fm., L. Cretaceous

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